Marine Mammal Monitoring During Lamont-Doherty Earth Observatory's Seismic Program in the Southeast Caribbean Sea and Adjacent Atlantic Ocean, April–June 2004

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1315 East-West Hwy, Silver Spring, MD 20910-3282

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ACRONYMS AND ABBREVIATIONS

~	approximately
bar	1×10^5 Pascals (nearly identical to 1 atmosphere unit of pressure)
CBD	Center for Biological Diversity
CIBRA	Centro Interdisciplinare di Bioacustica e Ricerche Ambientali
CIC	Centro do Investigación de Cetacéos
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CPA	Closest Point of Approach
CV	Coefficient of Variation
dB re 1 μPa	decibels in relation to a reference pressure of 1 micropascal
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
ESA	(U.S.) Endangered Species Act
Ewing	R/V *Maurice Ewing*
ft	foot or feet (1 foot = 0.305 m)
f(0)	sighting probability density at zero perpendicular distance from the survey track line
GMT	Greenwich Mean Time
GIS	Geographic Information System
GPS	Global Positioning System
g(0)	probability of seeing a group located directly on the survey trackline
h	hour
IHA	Incidental Harassment Authorization
m	meter (1 m = 1.09 yards or 3.28 feet)
IUCN	International Union for the Conservation of Nature
km	kilometer (1 km = 3281 ft, 0.62 st.mi., or 0.54 n.mi.)
kt	knots (n.mi. per hour)
L-DEO	Lamont-Doherty Earth Observatory
MCS	Multi-Channel Seismic
MMC	Marine Mammal Commission
MMO	Marine Mammal [and sea turtle] Observer
MMPA	(U.S.) Marine Mammal Protection Act
NASS	North Atlantic Sightings Surveys
NMFS	National Marine Fisheries Service, U.S. Dept of Commerce
n.mi.	nautical mile (1 n.mi. = 1.15 statute miles or 1.853 km)
NSF	National Science Foundation
NVD	Night Vision Device
OBS	Ocean Bottom Seismometer
PAM	Passive Acoustic Monitoring
PI	Principal Investigator
psi	pounds per square inch
RDT	Rotational Directional Transmission
rms	root mean square (a type of average), averaged over duration of airgun pulse
R/V	Research Vessel
s	second
SAM	surface active/mill
scfm	standard cubic feet per minute
SD	standard deviation
SE	Southeast
SJII	R/V *Seward Johnson II*
TTS	Temporary Threshold Shift
UNOLS	University-National Oceanographic Laboratory System
UT	University of Texas
μPA	micropascal

EXECUTIVE SUMMARY

Introduction

This document serves to meet reporting requirements specified in an Incidental Harassment Authorization (IHA) issued to Lamont-Doherty Earth Observatory (L-DEO) by the National Marine Fisheries Service (NMFS) on 16 April 2004. The IHA (in Appendix A) authorized non-lethal takes of certain marine mammals incidental to a marine seismic survey in the Southeast (SE) Caribbean Sea and adjacent North Atlantic Ocean. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the U.S. Marine Mammal Protection Act (MMPA). Cetaceans exposed to airgun sounds with received levels ≥160 dB re 1 µPa (rms) might be sufficiently disturbed to be "taken by harassment". "Taking" would also occur if marine mammals close to the seismic activity experienced a temporary or permanent reduction in their hearing sensitivity, or reacted behaviorally to the airgun sounds in a biologically significant manner.

It is not known whether, under field conditions, seismic exploration sounds cause temporary or especially permanent hearing impairment in any marine mammals or sea turtles that occur close to the seismic source. Nonetheless, to minimize the possibility of any injurious effects (auditory or otherwise), and to document the extent and nature of any disturbance effects, NMFS requires that seismic programs conducted under IHAs include provisions to monitor for marine mammals and sea turtles, and to shut down or "power down" the airguns when mammals or turtles are detected within designated safety radii. Safety radii were defined for cetaceans and sea turtles based on the distances within which the received levels of L-DEO's airgun sounds diminish to 180 dB re 1 µPa (rms) in different water depths. For the full 20-airgun array used in this survey the corresponding distance criteria were 3500 m in shallow water (<100 m depth), 1350 m in intermediate water depths (100–1000 m), and 900 m in deep water (>1000 m).

Southeast Caribbean Seismic Program Described

The survey encompassed an area from 59º to 71ºW and ~10º to 15ºN in the SE Caribbean Sea and adjacent North Atlantic Ocean. The seismic survey was conducted in the Exclusive Economic Zones (EEZ) of several nations in the SE Caribbean (including Venezuela, Aruba, Bonaire, Curaçao, and Trinidad and Tobago), as well as in international waters. Water depths within the study area ranged from ~15 to 6000 m (49–19,685 ft). The main purpose of the study was to obtain seismic data to gather information on island arc movements and geometry.

This L-DEO project used one airgun configuration consisting of an array of 20 Bolt airguns with total volume 6947 in^3, deployed from the R/V *Maurice Ewing*. In addition, the *Seward Johnson II* (*SJII*), a non-seismic vessel, was used to deploy and retrieve Ocean Bottom Seismometers (OBSs), provide support for the *Ewing*, and conduct additional marine mammal and sea turtle monitoring. The *Ewing* and *SJII* departed San Juan, Puerto Rico, on 18 and 19 April 2004, respectively, and arrived in the SE Caribbean study area on 20 and 21 April, respectively. The *Ewing* conducted seismic operations in the SE Caribbean study area for ~40 days, departed the area 1 June, and returned to San Juan on 3 June 2004. The *SJII* returned to San Juan on 1 June 2004.

A 6-km (480 channels) digital streamer containing hydrophones was towed behind the *Ewing* to receive the returning seismic acoustic signals. In addition, a 250-m hydrophone array was towed by the *Ewing* to conduct passive acoustic monitoring (PAM) for cetacean calls. A multibeam bathymetric sonar and a lower energy 3.5 kHz sub-bottom profiler were also operated from the *Ewing* throughout all or much of the SE Caribbean survey. A standard 10.5 kHz depth sounding sonar was used occasionally in very shallow areas to avoid grounding in areas where nautical charts were insufficiently detailed; this type of sonar is routinely employed by sea-going vessels to monitor water depths.

Monitoring and Mitigation Description and Methods

A total of five trained marine mammal observers (MMOs) were aboard the *Ewing* throughout the period of operations, two of whom were experienced with PAM. Two additional MMOs were aboard the *SJII*. Both visual and acoustic monitoring were conducted from the *Ewing*; only visual monitoring was conducted from the *SJII*.

- The primary purposes of the monitoring and mitigation effort aboard the *Ewing* were the following: ***(A)*** Provide real-time sighting data needed to document the occurrence, numbers and behaviors of marine mammals and sea turtles near the seismic source. ***(B)*** Test the usefulness of real-time acoustic monitoring for detecting and localizing marine mammals during a seismic survey, as a complement to visual monitoring. ***(C)*** Implement a power down or shut down of the airguns when marine mammals or turtles were detected near or within the designated safety radii. ***(D)*** Monitor for marine mammals and sea turtles before and during ramp-up periods. ***(E)*** Determine the reactions (if any) of potentially exposed marine mammals and sea turtles. ***(F)*** Estimate the numbers of marine mammals potentially exposed to strong seismic pulses.
- The primary purpose of the visual observations from the *SJII* was to document any potentially harmed or injured marine mammals or sea turtles in areas where the *Ewing* had been operating. In addition, at the same time as the *SJII* deployed or retrieved the OBSs, the MMOs documented the numbers and behavior of marine mammals and sea turtles before and after the *Ewing* had been operating in those areas.

Aboard the *Ewing*, one or two MMOs watched for marine mammals and sea turtles at all times while airguns operated during daylight periods, and during all nighttime ramp-up periods, of which there were three. Two observers were on watch at most times (42 of 52 h) during operations in shallow (<100 m depth) water, when the safety radius was the largest (i.e., 3.5 km), and during lesser proportions of the hours when the *Ewing* was operating in deeper waters (180 of 458 h). At least one MMO was on call during nighttime observations. During night periods when MMOs were not on duty, the bridge crew watched for marine mammals and sea turtles near the vessel with the naked eye as part of their normal watch duties. Visual observers also conducted watches during daytime periods when the source vessel was underway but the airguns were not firing.

In addition, 24-hr PAM was conducted by MMOs aboard the *Ewing*. The primary purpose of the acoustic monitoring was to aid visual observers in detecting calling marine mammals, particularly during periods with poor observation conditions, including high sea states, fog, or darkness, when visual monitoring is largely or totally ineffective. This was the first L-DEO project for which the IHA required use of PAM. Although PAM was used throughout the cruise, the operational procedures were still under development. Thus, use of PAM during this project was considered a field test of its utility for monitoring and mitigation purposes. Challenges encountered during the study included the following: • simultaneous deployment and operation of the PAM hydrophone array with the *Ewing*'s 6-km-long hydrophone streamer and the full 20-airgun array; • locating calling cetaceans given the limited maneuverability of the *Ewing* while towing the airgun array and streamer; and • vessel and airgun noise. As a result, numerous "start-up" difficulties were encountered that required continual problem-solving and adjustments in the field. However, the results also demonstrated the utility of the SEAMAP PAM system in detecting numerous cetacean groups that were not detected visually in the daytime as well as at night.

The visual MMOs aboard both vessels scanned the surface of the water around the vessels for marine mammals and sea turtles. The MMOs used 7 × 50 reticle binoculars, 25 × 150 Big-eye binoculars (only available on the *Ewing*), the naked eye, and (at night) night vision devices (NVDs). When cetaceans were sighted, the distance from the observation point (flying bridge or bridge) to the nearest member of the marine mammal group was estimated using reticles on one ocular lens of the binoculars. When a cetacean (or sea turtle) was detected in or approaching the safety radius in effect at the time, the visual MMO phoned the airgun operators to power down or shut down the airguns. The acoustic MMO and geophysical scientists were phoned to communicate the presence of cetaceans even if these were well outside the safety radius.

Aboard the *Ewing*, an acoustic MMO listened with headphones or speakers and simultaneously monitored a real-time spectrogram display associated with the SEAMAP Cetacean Monitoring System (SEAMAP), while listening and "watching" for marine mammal calls. When a calling cetacean was detected, the acoustic MMO phoned the visual MMOs, and communicated the presence of cetaceans.

Aboard the *Ewing*, mitigation procedures that were implemented, as required by the IHA, included the following: ***(1)*** To the extent practical, changes in vessel heading and speed to avoid marine mammals ahead of the vessel. ***(2)*** Limitations on when the airguns could start operating, and use of a ramp-up procedure whenever the airguns were started after periods without airgun operations or after prolonged operations with 1 airgun. ***(3)*** Immediate power downs or shut downs of the airguns whenever marine mammals or sea turtles were detected within or about to enter the safety radius applicable to the seismic source in use and the water depth at the time. A power down was a reduction to one operating airgun, whereas a shut down involved complete cessation of airgun operations. More stringent mitigation measures were implemented during this cruise as compared to previous L-DEO cruises.

Monitoring Results

L-DEO's SE Caribbean marine mammal monitoring program included the largest marine mammal survey effort undertaken to date in the SE Caribbean Sea. Over 900 h and >10,000 km of visual observation effort were conducted from two ships, and >800 h and >7300 km of acoustic monitoring effort were conducted from one of those ships. The project has provided, for the first time, survey data on the occurrence of cetaceans in the area across a wide span of longitudes during spring. In particular, prior to this effort, no surveys had been undertaken in the SE Caribbean Sea west of ~68ºW.

Table ES.1 summarizes the total effort and numbers of marine mammals and sea turtles detected by both ships with and without airguns operating. The *Ewing* traveled a total of 9788 km during the entire trip, including 8189 km in the SE Caribbean study area and 1599 km in transit to and from the study area (Table ES.1). The *SJII* traveled a total of 9644 km, including 8504 km in the SE Caribbean study area and 1140 km in transit (Table ES.1). Seismic sources operated night and day from the *Ewing* during most of the study period.

Aboard the *Ewing*, a total of 510 h of visual observations were made in the study area and during transits to/from Puerto Rico along 4920 km of vessel track from 18 April to 3 June (Table ES.1). Aboard the *SJII*, a total of 394 h (5087 km) of visual observations were made from 19 April to 1 June within and in transit to/from Puerto Rico (Table ES.1). *Ewing* MMOs were on visual watch for 425 h (3662 km) of the total 755 h (6605 km) period while airguns were on (including ramp up). As anticipated, the full 20-airgun array operated during the majority (343 h, 2936 km) of the period that airguns were on while *Ewing* MMOs were observing. During 52 h (452 km), 16–19 airguns were operating, typically during turns between seismic lines. One airgun operated for 12 h (106 km) and airgun ramp ups occurred during 13 h (110 km) while MMOs were on watch.

TABLE ES.1. Summary of effort and sightings made from the *Ewing* and *SJII* within and in transit to/from Puerto Rico in the SE Caribbean and adjacent North Atlantic seismic study area, 18 April–3 June 2004.

	Airguns On [1]	Airguns Off [2]	Total
Total *Ewing* Operations			
h (km)	755 (6605)	329 (3183)	1084 (9788)
Total *SJII* Operations			
h (km)	N/A	1052 (9644)	1052 (9644)
***SJII* Observer Effort**			
h (km)	N/A	394 (5087)	394 (5087)
***Ewing* Observer Effort**			
h (km)	425 (3662)	85 (1258)	510 (4920)
***Ewing* Acoustic Monitoring Effort**			
Day			
h (km)	421 (3658)	16 (129)	437 (3787)
Night			
h (km)	379 (3142)	27 (420)	406 (3562)
Total h (*includes 3 h undet.)	800	43	846*
Total km (*incl. 26 km undet.)	6800	549	7375*
***SJII* Cetacean Visual Sightings**			
No. Grps (No. Indiv.)	N/A	26 (927) [3]	26 (927) [3]
***Ewing* Cetacean Visual Sightings**			
No. Grps (No. Indiv.)	18 (301)	3 (66)	21 (367)
Total Cetacean Groups Sighted (No. Indiv.)	18 (301)	29 (993) [3]	47 (1294) [3]
***Ewing* Cetacean Acoustic Encounters[4]**			
Day	34	0	34
Night	43	1	44
Total	77	1	78

[1] Airguns on includes ramp up and when 1-20 airguns were operating.

[2] Airguns off includes times > 2 min without airguns on.

[3] Includes 1 dead floating and decomposing fin whale sighted by MMOs aboard the SJII. See Appendix B.

[4] An acoustic encounter was defined as cetacean calls of the same species or group separated by <1 h.

A total of 846 h (7375 km) of acoustic monitoring was conducted from the *Ewing* on 20 April to 1 June 2004, all within the seismic study area. This effort was almost equally divided between daytime and nighttime periods (Table ES.1). Nearly all (95%) acoustic monitoring effort occurred while airguns were operating.

A total of 28 marine mammal species and 6 sea turtle species may occur at least seasonally in the SE Caribbean study area. However, several of those species are rarely sighted or have not been positively identified there. Ten cetacean species and two sea turtle species (leatherback and hawksbill) were positively identified by visual observations in the SE Caribbean study area. Eight different cetacean species were seen from the *Ewing* and 5 different cetacean species were seen from the *SJII.* Only one of these species (the sperm whale) was positively identified by acoustic monitoring alone. Six additional cetacean species were seen and heard simultaneously from the *Ewing*, and there were numerous additional acoustic-only detections of unidentified dolphins. An estimated 1294 cetaceans were observed in 47 groups during the SE Caribbean survey (Table ES.1). Of this total, 21 groups were seen from the *Ewing* and 26 groups were seen from the *SJII*. The *SJII* total includes one floating, dead and decomposing fin whale. An independent review by a panel of cetacean experts, including NMFS and the Regional Coordinator of the Centro do Investigación de Cetacéos (CIC) in Venezuela, concluded that the death of the whale was not related to the *Ewing*'s seismic operations. No harmed or injured animals potentially associated with the operations were sighted. Unidentified whales and unidentified dolphins (n = 7 of each) were the most commonly seen groups. The most commonly-identified species were bottlenose, Atlantic spotted, and long-beaked common dolphins; six groups of each of these species were identified. The long-beaked common dolphin (n = 734) and Atlantic spotted dolphin (n = 229) were the most numerous cetaceans given their larger average group sizes. No pinnipeds or sirenians were seen during the survey. No humpback whales were identified, consistent with the fact that most (if not all) humpbacks would be expected to migrate north before the start of this project in late April.

A total of 78 acoustic encounters with calling cetaceans were detected from the *Ewing* during nearly 24 h/day of PAM (Table ES.1). All of the 66 acoustic-only detections were unidentified dolphins (n = 61) or sperm whales (n = 5). Nearly all (99% of 78) acoustic encounters occurred during periods when the airguns were operating. Acoustic encounters with delphinids were more common at night (11.5/1000 km) than during the day (7.4/1000 km), based on 63 unidentified dolphin encounters plus encounters with 6 dolphin groups identified to species through visual/acoustic matches. Overall, 12 of the 21 cetacean groups sighted from the *Ewing* were matched with concurrent acoustic encounters involving 7 different odontocete species.

Cetaceans apparently tended to avoid and/or change their behavior in response to seismic sounds produced by the *Ewing*. Observed cetacean densities, as determined from visual observations, were lower during seismic vs. non-seismic periods. During seismic periods, apparent densities were 55% and 35% of those during non-seismic periods in water depths 100–1000 m and >1000 m, respectively. Comparison of distances at the closest point of approach (CPA) showed that cetaceans (especially delphinids) tended to be closer to the observation vessel when sighted during non-seismic vs. seismic periods. Delphinids freq-uently approached and sometimes bow-rode the *SJII*; however, they were never seen bow-riding the *Ewing* whether or not the airguns were operating, and only infrequently approached it. These results are consistent with either localized displacement of cetaceans when the airguns were operating, or a change in their behavior, upon exposure to airgun sounds, that made them less conspicuous to visual observers.

Number of Marine Mammals Potentially Impacted

It is difficult to obtain meaningful estimates of "take by harassment" for several reasons. These include problems in estimating the number of cetaceans present in the area, difficulty in determining appropriate take criteria, variability in sound propagation, and variability in sounds received by marine mammals associated with depth. Any large cetaceans or beaked whales that might have been exposed to received sound levels ≥160 dB re 1 µPa (rms), and delphinids exposed to received levels of ≥170 dB re 1µPa, were assumed to have been potentially disturbed. The numbers of cetaceans observed from the *Ewing* during the SE Caribbean survey that were within various (160 dB, 170 dB, 180 dB) exposure zones around the seismic source provide estimates of the numbers of cetaceans potentially affected by seismic sounds. The predicted 180 dB radii for the 20-gun array were 900 m, 1350 m and 3500 m in deep, intermediate, and shallow waters, respectively.

During this project, nine cetacean groups involving ~245 individual cetaceans were sighted within the 180 dB safety radii around the operating airguns; however, only four of these groups are likely to have actually received airgun sounds ≥180 dB re 1 μPa before the airguns were powered down or shut down. Seven of eight groups of delphinids seen during seismic operations were sighted within the 170 dB radius of the airguns and were potentially exposed to sounds that might have affected their behavior. All other cetacean sightings (n = 9) during seismic were within the 160 dB radius and may have been exposed to sounds that might have affected their behavior. Of the nine cetacean groups for which a power down (to a single operating airgun) had to be implemented, two groups also approached the much smaller safety radius of the one operational airgun, resulting in a precautionary complete shut down of all airguns. These two groups, as well as two other groups for which shut downs were not necessary, were likely to have been exposed to levels ≥180 dB. In addition, the *Ewing* seismic sources were powered down twice for two sea turtles within or approaching the 180 dB safety zones.

The densities of cetaceans found in the SE Caribbean study area during mid-April to early June 2004 were lower for some species than had been found by a previous (winter 2000) survey, but similar to previous results for other species. The lower densities of some cetaceans found in spring 2004 could be due to a number of factors. These include differences in the survey seasons (winter survey in 2000; spring survey in 2004), changes in biological productivity between years, differences in survey methods, and/or anthropogenic factors, such as presence of the *Ewing*, commercial seismic vessels, and oil-production activities. The lack of humpback whale sightings during the present spring project was no doubt attributable to the season, but otherwise it is not possible to determine which factors had the largest impact on cetacean density in the area. However, given the observed densities during both seismic and non-seismic periods, it appears that the number of marine mammals exposed to strong airgun sounds during L-DEO's SE Caribbean seismic survey was well below the "take by harassment" authorized in the IHA issued to L-DEO.

L-DEO's marine mammal and sea turtle monitoring and mitigation program combined various approaches to reduce and mitigate the likelihood of exposing these species to potentially harmful levels of airgun sounds. Results of the SE Caribbean project confirm that no one monitoring or mitigation measure is entirely effective in detecting marine mammals or preventing exposure to strong airgun sounds. For example, the current PAM approach cannot be used by itself to implement mitigation measures aboard the *Ewing*, as distances to the detected cetaceans typically cannot be determined. Furthermore, the reliability of SEAMAP during the SE Caribbean cruise was limited by "start-up" complications and ongoing challenges associated with interfacing SEAMAP software and hardware with existing shipboard systems for the first time in the field during typical *Ewing* seismic operations. However, PAM detected odontocetes much more frequently than did visual techniques, during daytime as well as at night, when visual observations are ineffective. Thus, PAM is valuable in indicating when cetaceans are in the area near the ship. Results indicate that different monitoring and mitigation techniques can be complementary. The number of marine mammals potentially exposed to *Ewing* airgun sounds ≥180 dB re 1 μPa (rms) could be reduced in the future if calling cetaceans could be better localized.

1. INTRODUCTION

Lamont-Doherty Earth Observatory (L-DEO) conducted a marine seismic study from 18 April to 3 June 2004 in the Southeast (SE) Caribbean Sea and the adjacent North Atlantic Ocean (Fig. 1.1). The primary purpose of the study was to gather seismic data to obtain information on island arc movements and geometry. This information will be used to better understand the history and mechanical processes by which island arcs accrete to continents, deeply buried rocks are exhumed, and folded belts and different types of sedimentary basins form along oblique collision zones. An airgun array consisting of 20 Bolt airguns with a total discharge volume of 6947 in^3 was used as the energy source. Individual airguns ranged in chamber volume from 80 to 875 in^3.

Marine seismic surveys emit strong sounds into the water (Greene and Richardson 1988; Tolstoy et al. 2004a,b), and have the potential to affect marine mammals, given the known auditory and behavioral sensitivity of many such species to underwater sounds (Richardson et al. 1995). The effects could consist of behavioral or distributional changes, and perhaps temporary or permanent reduction in hearing sensitivity. Either behavioral/distributional or auditory effects could constitute "taking" under the provisions of the U.S. Marine Mammal Protection Act (MMPA) and the U.S. Endangered Species (ESA) Act, at least if the effects are considered to be biologically significant.

Numerous species of cetaceans inhabit the SE Caribbean Sea and adjacent Atlantic Ocean. These include various dolphins and other toothed whales, the Bryde's and minke whales, and several species listed as endangered under the ESA: humpback, sei, fin, blue, and sperm whales. Of these endangered species, only the humpback and sperm whales are common in the area. Also, the humpback whale occurs in the study area only seasonally, generally from January to March, and was not expected to occur there during the April–June study period. Other species of special concern in the area include the endangered leatherback, Kemp's ridley, and hawksbill sea turtles, and the threatened loggerhead, green, and olive ridley sea turtles. Pinnipeds do not occur regularly in the SE Caribbean Sea.

On 7 August 2003, L-DEO requested that the National Marine Fisheries Service (NMFS) issue an Incidental Harassment Authorization (IHA) to authorize non-lethal "takes" of marine mammals incidental to the airgun operations planned in the SE Caribbean Sea and adjacent Atlantic Ocean (LGL Ltd. 2003a). This survey work was originally proposed to occur from 11 January to 21 February 2004, but was later rescheduled to commence in mid-April, after most humpback whales had left the study area. The IHA was requested pursuant to Section 101(a)(5)(D) of the MMPA. An Environmental Assessment (EA) was also written to evaluate the potential impacts of the marine seismic survey in the SE Caribbean Sea (LGL Ltd. 2003b). That EA was adopted by the National Science Foundation (NSF), the federal agency sponsoring this seismic survey. The IHA was issued by NMFS on 16 April 2004 (NMFS 2004). The seismic cruise occurred from 18 April to 3 June 2004, and airgun operations occurred during 36 days within that 47-day period. The ship transit from San Juan, Puerto Rico, to the SE Caribbean study area occurred 18–20 April, and the return transit to San Juan occurred 1–3 June. The airguns did not operate during transits and were also shut down 23–27 April and 15–17 May.

This document serves to meet reporting requirements specified in the IHA. The primary purposes of this report are to describe the SE Caribbean seismic survey, to describe the associated marine mammal monitoring and mitigation programs and their results, and to estimate the numbers of marine mammals potentially affected by the project.

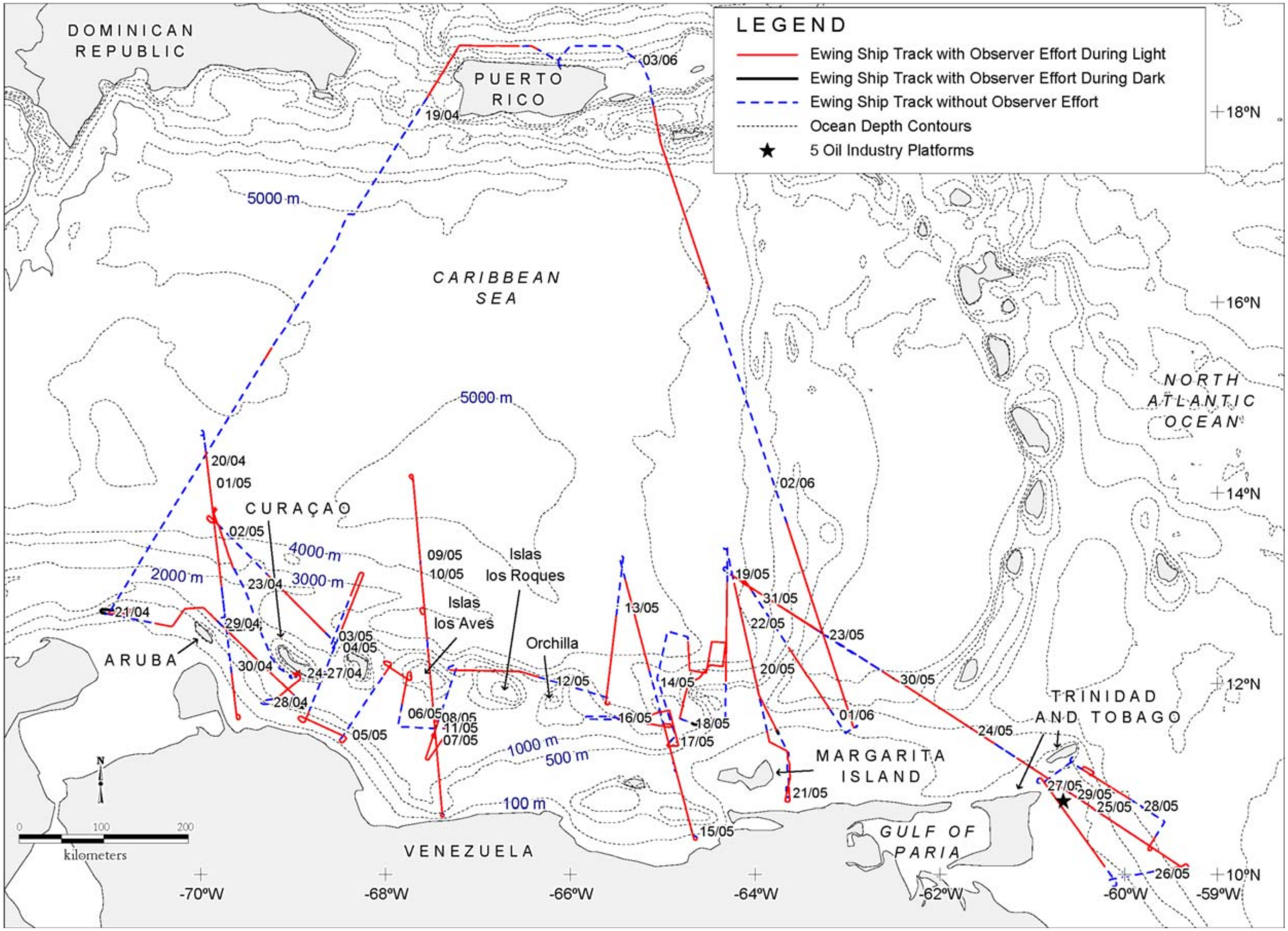

FIGURE 1.1. The study area and *Ewing* ship tracks, categorized by visual observation effort, for L-DEO's SE Caribbean and adjacent Atlantic seismic survey, 18 April–3 June 2004. Codes of the form ab/cd are day/month.

Incidental Harassment Authorization

Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the MMPA. Such disturbance falls within the MMPA definition of Level B harassment, which entails "disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering". "Taking" of marine mammals without special authorization is prohibited. However, under the 1994 amendments to the MMPA and regulations released in 1996, "citizens of the United States can apply for an authorization to take incidentally, but not intentionally, small numbers of marine mammals by harassment" (NMFS 1996). IHAs can be issued if "taking will have a negligible impact on the species or stock(s) of marine mammals and will not have an unmitigable adverse impact on the availability of the species or stock(s) for subsistence uses". IHAs can authorize unintentional harassment (disturbance) but not serious injury or mortality.

To minimize the possibility that marine mammals close to the seismic source might be exposed to levels of sound high enough to cause hearing damage or other injuries, IHAs issued to seismic operators call for a power down or shut down of the seismic source when mammals are seen within designated "safety radii". Under current NMFS guidelines, the safety radii around the arrays are customarily defined as the distances at which the received pulse levels diminish to 180 dB re 1 μPa (rms) for cetaceans and 190 dB for pinnipeds. The safety radii for the SE Caribbean seismic study were predicted based on a combination of acoustic modeling and empirical measurements. [L-DEO has developed a mathematical model to predict the sound field around their airgun configurations during operations in deep water. Empirical calibration data were collected by L-DEO in deep and shallow water of the Gulf of Mexico during operation of various airgun configurations, including a 20-airgun array similar to that used during the SE Caribbean study (Tolstoy et al. 2004a,b).] The safety radii are further described in Chapter 3. No serious injuries or deaths were anticipated, given the nature of the operations and the mitigation measures that were implemented, and none were documented in association with seismic operations. Continuous visual daytime monitoring was conducted by experienced marine mammal observers (MMOs) aboard the *Ewing* seismic vessel and the non-seismic support vessel R/V *Seward Johnson II* (*SJII*). One or two visual MMOs were on watch aboard each ship during daylight. In addition, 24-hr acoustic monitoring was conducted aboard the *Ewing* during airgun operations.

Although no serious injuries were expected or documented as a result of the seismic operations, the seismic survey operations described in Chapter 2 had the potential to "take" marine mammals by harassment. Sounds were generated by the airguns used during the seismic study, a multibeam bathymetric sonar, a sub-bottom profiler, occasionally one other echosounder, and by general vessel operations. Disturbance could occur at distances beyond the 180 dB safety (=shutdown) radii if marine mammals were exposed to moderately strong pulsed sounds generated by the airgun array or sonar (Richardson et al. 1995; Gordon et al. 2004). In general, disturbance effects are expected to depend on the species of marine mammal, the activity of the animal at the time, its distance from the sound source, and on the received level of the sound and the associated water depth.

A notice regarding the proposed issuance of an IHA for the SE Caribbean project was published by NMFS in the *Federal Register* on 21 October 2003, and public comments were invited (NMFS 2003). The Marine Mammal Commission (MMC) and the Center for Biological Diversity (CBD) were the two agencies or organizations that submitted comments (NMFS 2004).

On 16 April 2004, L-DEO received the IHA that had been requested for the SE Caribbean project, and on 4 May 2004 NMFS published a second notice in the *Federal Register* to announce the issuance of the IHA (NMFS 2004). The second notice responded to comments received by NMFS, and provided additional information concerning the IHA and the changes from the originally proposed IHA. A copy of the issued IHA is included in this report as Appendix A.

The IHA was granted to L-DEO on the assumptions that

- the numbers of marine mammals potentially harassed (as defined by NMFS criteria) during seismic operations would be "small",
- the long-term effects of such harassment on marine mammal populations would be negligible,
- no marine mammals would be seriously injured or killed, and
- the agreed upon monitoring and mitigation measures would be implemented.

Mitigation and Monitoring Objectives

The objectives of the mitigation and monitoring program were described in detail in L-DEO's IHA Application (LGL Ltd. 2003a) and in the IHA issued by NMFS to L-DEO (NMFS 2004; Appendix A). Additional explanatory material about the monitoring and mitigation requirements was published by NMFS in the *Federal Register* (NMFS 2003, 2004).

The main purpose of the mitigation program was to avoid or minimize potential effects of L-DEO's seismic survey on marine mammals and sea turtles. This required that L-DEO detect marine mammals within or about to enter the safety radius (safety zone), and in such cases initiate an immediate power down (or shut down if necessary) of the airguns. A power down involves greatly reducing the source level of the operating airguns, generally by ceasing the operation of all but one airgun. A shut down involves ceasing the operation of all airguns. An additional mitigation objective was to detect marine mammals or sea turtles within or near the safety radii prior to starting the airguns, or during ramp up toward full power. In these cases, L-DEO would delay or discontinue the ramp up until the safety radii was free of marine mammals or sea turtles for at least 30 minutes.

The primary objectives of the monitoring and mitigation program were as follows:

- **Aboard the *Ewing***: ***(A)*** Provide real-time sighting data needed to document the occurrence, numbers and behaviors of marine mammals and sea turtles near the seismic source. ***(B)*** Test the usefulness of real-time acoustic monitoring for detecting and localizing marine mammals during a seismic survey, as a complement to visual monitoring. ***(C)*** Implement a power down or shut down of the airguns when marine mammals or turtles were detected near or within the designated safety radii. ***(D)*** Monitor for marine mammals and sea turtles before and during ramp-up periods. ***(E)*** Determine the reactions (if any) of potentially exposed marine mammals and sea turtles. ***(F)*** Estimate the numbers of marine mammals potentially exposed to strong seismic pulses.
- **Aboard the *SJII*:** Document any potentially harmed or injured marine mammals or sea turtles in areas where the *Ewing* had been operating. In addition, while the *SJII* deploys or retrieves the OBSs, document the numbers and behavior of marine mammals and sea turtles before and after the *Ewing* operates in those areas.

Specific mitigation and monitoring objectives as identified in the IHA are shown in Appendix A. Mitigation and monitoring measures that were implemented during the SE Caribbean program are described in detail in Chapter 3.

The SE Caribbean study included two monitoring components that had not been present during many (or any) of the previous marine mammal monitoring efforts by L-DEO. ***(1)*** Passive acoustic monitoring (PAM): PAM had been used on a trial basis during the northern Gulf of Mexico cruise in May–June 2004 (LGL Ltd. 2003c), but not during subsequent cruises in the tropical Pacific, Norwegian Sea, or mid-Atlantic (Smultea and Holst 2003; MacLean and Haley 2004; Holst 2004). ***(2)*** Visual observations from a support vessel (the *SJII*) as well as from the seismic vessel (the *Ewing*): For the first time during L-DEO's seismic surveys, observations from a second vessel (the *SJII*) provided a basis for comparing systematic visual observations collected from two ships working simultaneously in the same region, one operating airguns most of the time, and one without airguns.

In addition, a number of amendments were made to mitigation measures that had been implemented during previous L-DEO seismic cruises (see Appendix A and Chapter 3). Some of these amendments were related to the fact that empirical measurements of sound levels from L-DEO's 20-airgun array (Tolstoy et al. 2004a,b) became available shortly before the present cruise. The data showed that received levels of sound from the *Ewing*'s airguns, and therefore safety radii, vary with water depth.

Report Organization

The primary purpose of this 90-day Report is to describe the 2004 seismic study that was conducted in the SE Caribbean Sea and adjacent Atlantic Ocean, including the associated monitoring and mitigation programs, and to present results as required by the IHA (see Appendix A). This report includes four chapters:

1. background and introduction (this chapter);
2. description of L-DEO's 2004 seismic study in the SE Caribbean Sea and adjacent Atlantic Ocean;
3. description of the marine mammal and sea turtle monitoring and mitigation requirements and methods, including a description of the safety radii used during the seismic study;
4. results of the marine mammal monitoring program, and estimated numbers of marine mammals potentially "taken by harassment" during this program; and
5. results of the monitoring and mitigation efforts for sea turtles.

Those chapters are followed by overall Acknowledgements and Literature Cited sections. In addition, there are six Appendices:

A. a copy of the IHA issued to L-DEO for this study;

B. a description of a fin whale carcass that was found during the study;

C. a description of the behavioral data that were collected;

D. a summary of the "ground-truthing" session for of the Night Vision Devices (NVDs);

E. conservation status of marine mammal species that might occur in the study area;

F. a summary of observation effort; and

G. details of the visual and acoustic detections made from the *Ewing* and *SJII*.

2. SOUTHEAST CARIBBEAN SEA SEISMIC SURVEY DESCRIBED

Introduction

L-DEO's seismic study in the SE Caribbean Sea aboard the *Ewing* took place from 18 April to 3 June 2004. The main purpose of the study was to obtain seismic data to gather information on island arc movements and geometry. That information will be used to better understand the history and mechanical processes by which island arcs accrete to continents, deeply buried rocks are exhumed, and folded belts and different types of sedimentary basins form along oblique collision zones. The interplay of the crust and subcrustal lithosphere during arc accretion, metamorphic belt exhumation, and subduction polarity reverses will be examined based on the seismic data that were collected. In addition, the flow patterns of the sublithospheric mantle beneath the plate boundary and northern South America as a whole, and beneath the right lateral shear zone between them, will be examined.

The survey encompassed an area from 59º to 71ºW and ~10º to 15ºN in the SE Caribbean Sea and adjacent Atlantic Ocean off the coast of Venezuela (Fig. 1.1). The seismic survey was conducted in the Exclusive Economic Zones (EEZ) of several nations in the SE Caribbean (including Venezuela, Aruba, Bonaire, Curaçao, and Trinidad and Tobago), as well as in international waters. Water depths within the study area ranged from ~15 to 6000 m (49–19,685 ft.).

During the SE Caribbean seismic study, L-DEO used the R/V *Maurice Ewing* (Fig. 2.1A) to tow the airguns and hydrophone streamer. The *Ewing* was self-contained, with the crew living aboard the vessel. Procedures used to obtain data during the SE Caribbean Sea study were similar to those used during previous seismic surveys by L-DEO, e.g., off the coast of Newfoundland in the North Atlantic (Holbrook et al. 2003). The SE Caribbean Sea program used conventional seismic reflection techniques to characterize the earth's crust. A towed 20-gun array of Bolt airguns was used as the energy source. Compressed air supplied by compressors on board the source vessel powered the airgun array. A 6-km streamer containing hydrophones was towed behind the *Ewing* to receive the returning acoustic signals. A 250-m SEAMAP Cetacean Monitoring System (SEAMAP) consisting of a 2-channel hydrophone array was also towed behind the vessel to detect calling cetaceans (see Chapter 3).

A multibeam bathymetric sonar and a lower-energy sub-bottom profiler were operated from the source vessel throughout most of the cruise, including transits to and from port as well as during the seismic survey. In addition, another depth-sounding sonar was occasionally used as needed to assist in safe navigation through shallow, poorly-charted waters.

In addition to the *Ewing*, L-DEO used the R/V *Seward Johnson II (SJII)* to assist the *Ewing* in gathering data during the SE Caribbean seismic study. The *SJII* participated in this project from 19 April to 2 June. The *SJII* was a self-contained research vessel (Fig. 2.1B), with the crew living aboard the vessel. The *SJII*'s primary purpose during this project was to deploy and retrieve Ocean Bottom Seismometers (OBSs) along designated OBS survey lines.

Geophysical data acquisition activities aboard the *Ewing* and *SJII* were conducted by L-DEO with on-board assistance from the scientists who proposed and designed the study. The scientists aboard the *Ewing* were headed by Dr. Dale Sawyer of Rice University, Houston, TX, and Dr. Paul Mann of the University of Texas Institute for Geophysics, Austin, TX. The scientists aboard the *SJII* were headed by Dr. Gail Christeson, also of the University of Texas Institute for Geophysics. MMOs were aboard the *Ewing* throughout the period of operations from 18 April to 3 June to implement provisions of the IHA

A

B

FIGURE 2.1. Vessels used by L-DEO for the SE Caribbean project: ***(A)*** the source vessel, the R/V *Maurice Ewing*; and ***(B)*** the support vessel, R/V *Seward Johnson II*.

issued by NMFS for the SE Caribbean seismic study (Appendix A). MMOs were also aboard the *SJII* throughout the study period, 19 April to 2 June.

The following sections provide additional details about the equipment used for the seismic study and its mode of operation, insofar as necessary to satisfy the reporting requirements of the IHA (Appendix A) and as relevant to marine mammal (and sea turtle) monitoring and mitigation.

R/V Maurice Ewing Vessel Specifications

The *Ewing* has a length of 70 m (230 ft), a beam of 14.1 m (46.3 ft), and a draft of 4.4 m (14.4 ft). The *Ewing* has four 1000-kW diesel generators that supply power to the ship. The ship is powered by four 800-hp electric motors that, in combination, drive a single 5-blade propeller in a Kort nozzle and a single-tunnel electric bow thruster rated at 500 hp. At the typical operation speed of 7.4–9.3 km/h (4–5 knots) during seismic acquisition, the shaft rotation speed is about 90 rpm. When not towing seismic survey gear, the *Ewing* cruises at 18.5–20.4 km/h (10–11 knots) and has a maximum speed of 25 km/h (13.5 knots). It has a normal operating range of about 31,500 km (17,000 n.mi.). Given the presence of the streamer and airgun array behind the vessel, the turning rate of the vessel while this gear was deployed was limited to about five degrees per minute. Thus, the maneuverability of the vessel was limited during operations.

Other details of the *Ewing* include the following:

Owner:	National Science Foundation
Operator:	Lamont-Doherty Earth Observatory of Columbia University
Flag:	United States of America
Date Built:	1983 (modified in 1990)
Gross Tonnage:	1978
Fathometers:	3.5 and 12 kHz hull mounted transducers; Furuno FGG80 echosounder; Furuno FCU66 echosounder recorder
Bottom Mapping Equipment:	Atlas Hydrosweep DS-2, 15.5 kHz (details below)
Compressors for Air Guns:	LMF DC, capable of 1000 scfm at 2000 psi
Accommodation Capacity:	21 crew plus 3 technicians and 26 scientists

The *Ewing* also served as a platform from which vessel-based MMOs watched for marine mammals and sea turtles. The flying bridge was the best vantage point, and afforded good visibility for the observers. However, visibility immediately astern of the *Ewing* was slightly restricted because of an intervening superstructure (Fig. 2.2). L-DEO constructed an MMO station with an overhead structural canopy on the flying bridge for shelter from sun, wind, and rain (Fig. 2.3).

R/V Seward Johnson II Vessel Specifications

The *SJII* was used to deploy and retrieve the OBSs. This vessel is part of the University-National Oceanographic Laboratory System (UNOLS). The *SJII* has a length of 62 m (204 ft), a beam of 11 m (36 ft), and a draft of 3.7 m (12 ft). The *SJII* is powered by two diesel marine engines of 1700 hp each. The *SJII* cruises at 20 km/h (11 knots) and has a maximum speed of 24 km/h (13 knots). It has a maximum endurance of 30 days at sea, and its normal operating range is ~11,112 km (6000 n.mi.). The *SJII* did not deploy airguns and its day-to-day operations were similar to those of other vessels that worked in or passed through the study area.

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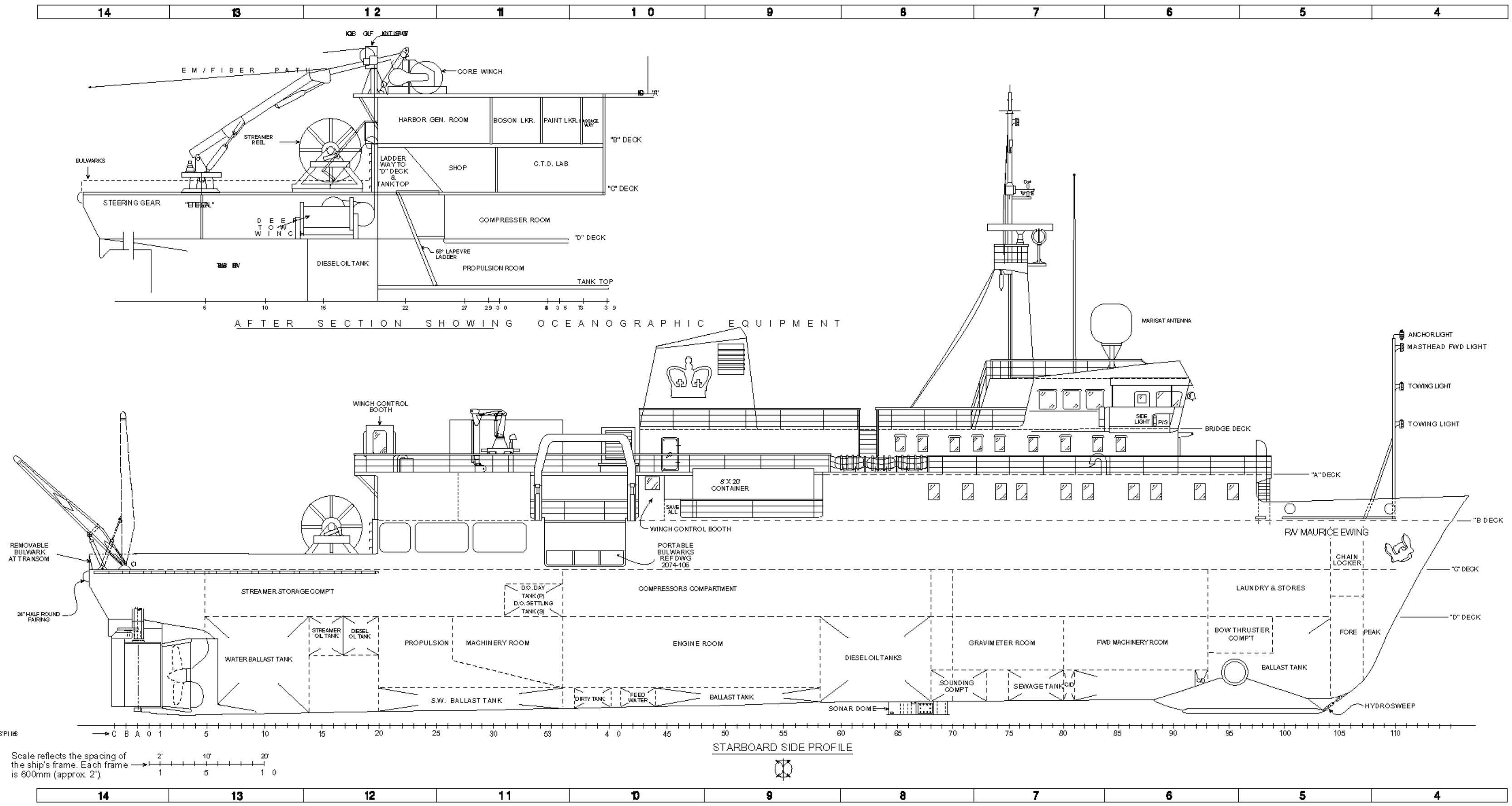

FIGURE 2.2. Schematic starboard profile of the R/V *Maurice Ewing*.

FIGURE 2.3. A view of the flying bridge of the R/V *Maurice Ewing* showing the MMO station.

Other details of the *SJII* include the following:

Owner:	Harbor Branch Oceanographic Institution, Inc.
Operator:	Harbor Branch Oceanographic Institution, Inc.
Flag:	United States of America
Year Built/Converted:	1984/1994
Accommodation Capacity:	40 (including crew)

The *SJII* also served as a platform from which vessel-based MMOs watched for marine mammals and sea turtles. The flying bridge was the best vantage point, and afforded good visibility for the MMOs.

Airgun Array Characteristics

Figure 2.4 shows the gun positions of the 20-airgun array deployed by the *Ewing* during the study. The airguns were deployed from booms extending 18 m (59 ft) from midships to the port and starboard stern quarters of the *Ewing* (Fig. 2.5). During operations, the airguns were suspended in the water from air-filled floats and were oriented horizontally. The airguns were suspended ~7.5 m below the water surface. In Figure 2.5, the floats and airguns are out of the water. The characteristics of the 20-airgun array used during the SE Caribbean Sea study are summarized in Table 2.1.

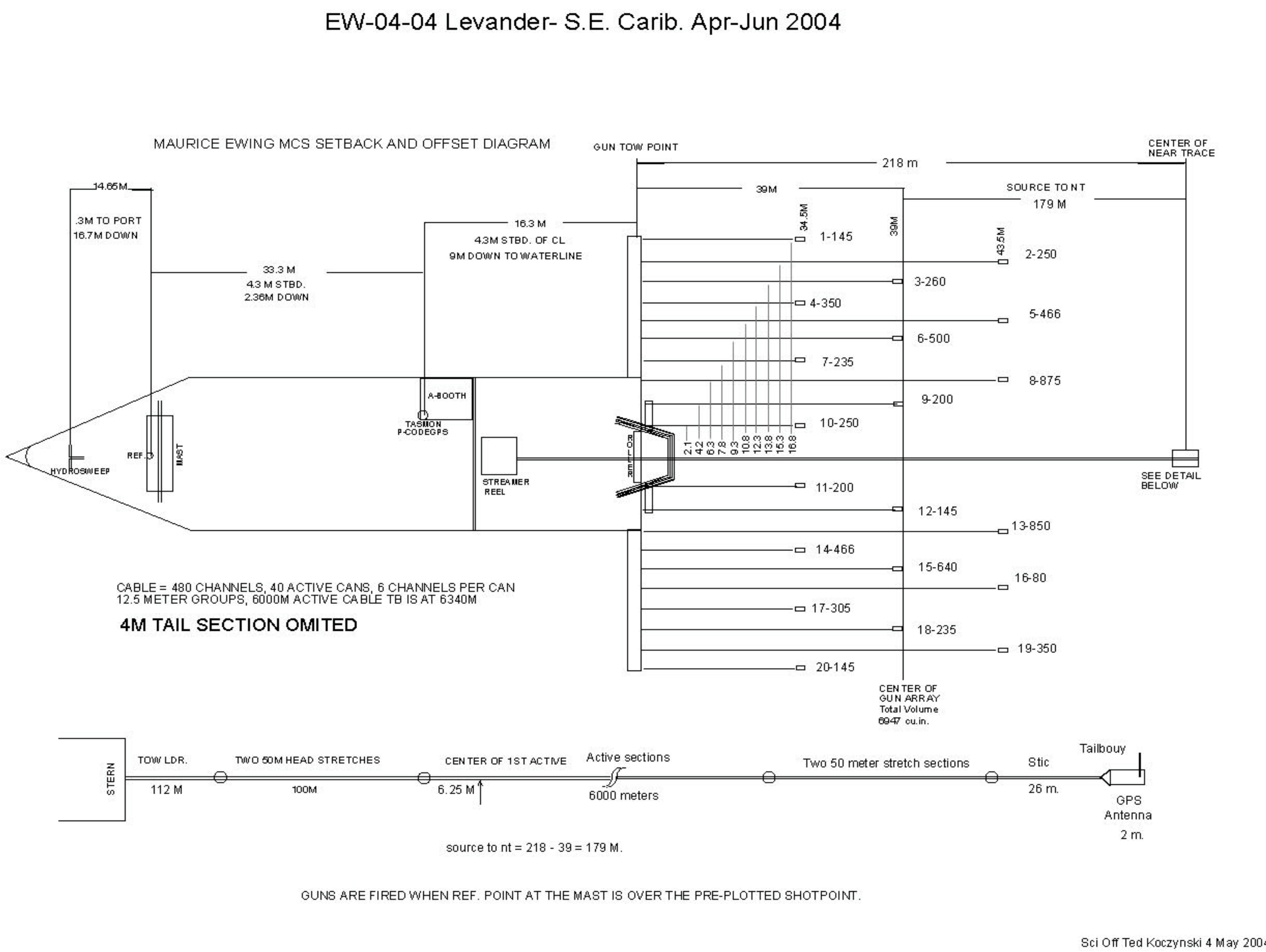

FIGURE 2.4. Configuration of the 20-gun 6947-in^3 array used aboard the R/V *Maurice Ewing* during the SE Caribbean study.

FIGURE 2.5. Airgun array being deployed from the gunbooms of the R/V *Maurice Ewing.*

TABLE 2.1. Specifications of the 20-airgun array used during the SE Caribbean seismic study.

Energy Source	Twenty 2000 psi Bolt airguns of 80–875 in^3
Source output (downward)[1]	0-pk is 58 bar-m (255 dB re 1 μPa·m); pk-pk is 124 bar-m (262 dB)
Towing depth of energy source	7.5 m
Air discharge volume	6947 in^3
Dominant frequency components	0–188 Hz
Gun positions used	see Fig. 2.4
Gun volumes at each position	see Fig. 2.4

[1] All source level estimates are for a filter bandwidth of approximately 0–250 Hz.

The 20-airgun array and a streamer containing hydrophones were towed by the *Ewing* along predetermined survey lines (Fig. 2.6). Seismic pulses were typically emitted at intervals of ~60 seconds during OBS lines and ~20 seconds during MCS (multi-channel seismic) lines (Fig. 2.6). The 60-s and 20-s spacings correspond to shot intervals of ~150 m (492 ft) and 50 m (164 ft), respectively. One OBS seismic line (line BOL-36) was shot at ~175-m shot intervals (Fig. 2.6). The wide spacing of shots along OBS lines was to minimize previous shot noise during OBS data acquisition, and the exact spacing depended on water depth. The 20-gun array included airguns ranging in chamber volume from 80 to 875 in^3, with a total volume of 6947 in^3 (Fig. 2.4). This total volume was considerably reduced from the ~8600 in^3 used by L-DEO during 20-airgun operations in the Gulf of Mexico calibration study (Tolstoy et al. 2004a,b). The 20 airguns were spaced in a rectangle of dimensions of 43.5 m or 143 ft by 9 m or 30 ft (Fig. 2.4); these dimensions are similar to those of the standard 20-airgun array.

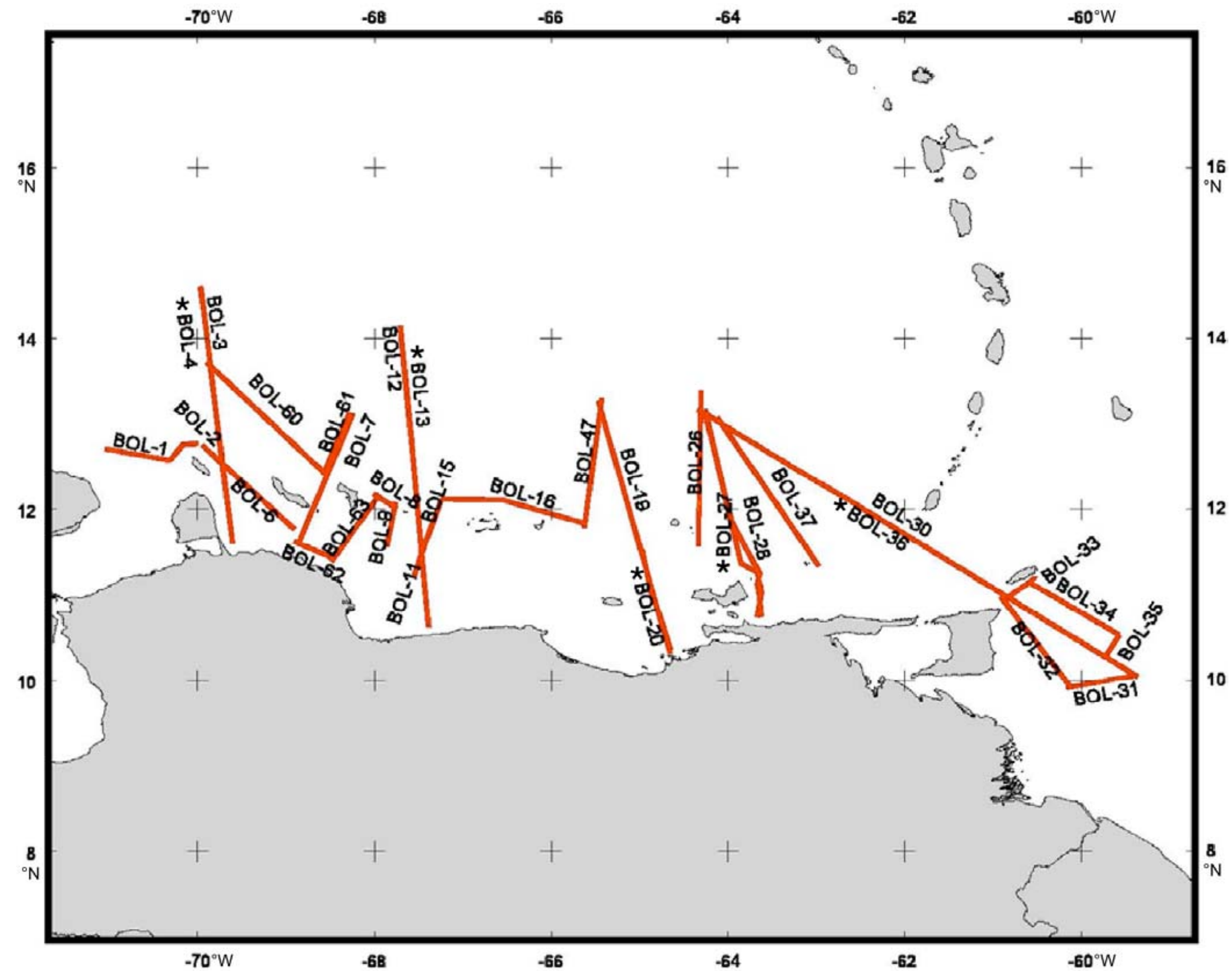

FIGURE 2.6. Locations of MCS and OBS seismic survey lines acquired from the R/V *Maurice Ewing* during L-DEO's marine seismic study in the SE Caribbean and adjacent Atlantic Ocean, 18 April – 3 June 2004. The five OBS lines are identified with an asterisk (*) and consisted of lines **BOL-4, BOL-13, BOL-20, BOL-27** and **BOL-36**; OBS lines were shot at ~150-m shot intervals with the exception of BOL-36, which was shot at ~175-m intervals. All remaining survey lines are MCS lines shot at ~50-m intervals. See text.

The bandwidth considered in defining the source levels extends up to ~250 Hz. Those source levels are as conventionally defined by geophysicists, and represent the nominal source level for downward propagation of low-frequency energy. Nominal source levels would be somewhat higher if the small amount of energy at higher frequencies were considered. Because the actual source is a distributed sound source (20 guns) rather than a single point source, the highest sound level measurable at any location in the water would be less than the nominal source level (Caldwell and Dragoset 2000). Also, because of the directional nature of the sound from the airgun array, the effective source level for sound propagating in near-horizontal directions would be substantially lower.

OBS Deployment and Retrieval

Along selected OBS lines, seismometers were positioned by the *SJII* before the *Ewing* conducted airgun operations in that area. After each OBS line was shot, the *SJII* retrieved the OBSs, downloaded the data, and refurbished the OBS units before redeploying them along the next OBS line that was to be shot. During the SE Caribbean cruise, there were five sets of deployments of OBSs, one deployment along each of the five OBS lines (Fig. 2.6). OBSs were also deployed at two other locations near each line to fill data gaps between islands.

Navigation, Operating Areas, and Dates

The *Ewing* departed San Juan, Puerto Rico, on 18 August 2004 and arrived in the SE Caribbean study area on 20 April. The *SJII* departed San Juan on 19 April and arrived in the study area on 21 April. A chronology of the study is presented in Table 2.2. The *Ewing*'s airgun operations commenced on 20 April and finished on 1 June. The *Ewing* and *SJII* interrupted the seismic study on 23–27 April because the *Ewing* had to go to port at Curaçao to repair a broken rudder and to deal with a crew medical emergency (Table 2.2). Seismic airgun operations ceased again 15–17 May when the *SJII* discovered a floating, dead and decaying fin whale. The whale's death was determined to be unrelated to the *Ewing*'s airgun operations based on review by a panel of independent experts (see Appendix B and Chapter 4). Although the airguns did not operate for these three days, the geophysical scientists aboard the *Ewing* conducted an ancillary non-seismic bathymetry study during that period. During the study period the *SJII* made several trips to ports or islands for crew changes, equipment repair, etc. The *SJII* departed the SE Caribbean study area on 31 May and arrived in San Juan on 2 June. The *Ewing* left the study area on 1 June and arrived in San Juan on 3 June 2004.

Throughout the study, position, speed, and activities of the *Ewing* were logged digitally every minute. In addition, the position of the *Ewing,* water depth, and information on the airgun array were logged for every airgun shot while the *Ewing* was on line and collecting geophysical data. The geophysics crew kept a written log of events, as did the MMOs while on duty. Aboard the *Ewing*, the MMOs also recorded the number and volume of guns that were firing when the *Ewing* was offline (e.g., turning from one line to the next) or was online but not recording data (e.g., during airgun or computer problems).

Aboard the *SJII*, the Global Positioning System (GPS) logged the vessel's position every minute. The MMOs on the *SJII* also recorded the *SJII*'s activity while they were on watch. The two primary activities conducted by the *SJII* were deploying/retrieving OBSs and transiting between OBS survey lines or other destinations. While deploying or retrieving OBSs, the *SJII* moved slowly (about 0–2 kt) and intermittently, typically in a non-linear fashion while maneuvering into position or searching for OBSs to retrieve. During transit, the *SJII* traveled at speeds of ~9–10 kt, generally in a linear fashion.

TABLE 2.2. Chronology in Greenwich Mean Time (GMT) of events during the April–June 2004 L-DEO seismic study in the SE Caribbean Sea and adjacent Atlantic Ocean.

Date in 2004	Time	Event Description
18 April	12:03	*Ewing* departs San Juan, Puerto Rico; 15.5 kHz multibeam sonar and 3.5 kHz depth sounder started; *Ewing* MMO effort begins
19 April	12:10	*SJII* departs San Juan; depth finder started
20 April	10:10	*Ewing* arrives in western part of study area near Line BOL-1 (see Fig. 2.6)
20 April	11:30	*Ewing* begins deploying SEAMAP hydrophone array, MCS streamer, and airguns
20 April	15:40	Begin PAM from *Ewing*
20 April	20:01	*Ewing*'s first airgun shot, Line BOL-1
21 April	02:03	*SJII* starts deploying OBSs on Line BOL-4 (see Fig. 2.6)
22 April	22:58	*Ewing* MMO effort stops; *Ewing* headed to Curaçao for mechanical repairs
23-26 April		*Ewing* and *SJII* in port at Curaçao to repair steering
27 April	18:00	*Ewing* departs Curaçao for study area and resumes airgun operations
30 April	11:50	*SJII* departs Curaçao for study area
5 May	15:00-18:00	*SJII* in port at Curaçao for crew change
15 May	13:30	*SJII* finds floating, dead decaying fin whale
15 May	15:00	*Ewing* shuts down all airguns to consult with L-DEO, NSF & NMFS regarding dead whale
16 May	01:17	PAM from *Ewing* ceases
16 May	10:00	*SJII* in port at Trinidad to refuel & for crew change
17 May	22:46	*Ewing* resumes airgun operations
17 May	22:50	PAM from *Ewing* recommences
18 May	22:40	*SJII* departs Trinidad, returns to study area
25 May	12:00	*SJII* anchors at King's Bay to repair OBSs
28 May	11:00	*SJII* departs King's Bay, returns to study area
31 May	20:40	*SJII* departs SE Caribbean study area
1 June	~05:30	*Ewing* airgun work ends at southern end of Line BOL-37 (see Fig. 2.6); *Ewing* departs SE Caribbean study area
1 June	06:00	PAM from *Ewing* ends
2 June	11:00	*SJII* arrives in San Juan
2 June	21:00	*Ewing* visual MMO effort ends
3 June	~08:00	*Ewing* arrives in San Juan

The *Ewing* traveled a total of 9788 km: 8189 km at the SE Caribbean study area and 1599 km in transit to and from the study area (Table ES.1). While in the study area, airguns operated from the *Ewing* during both day and night for a total of 755 h during which the *Ewing* traveled 6605 km, and were off for a total of 329 h during which the *Ewing* traveled 3183 km. More kilometers of seismic profile were collected than anticipated. See Chapter 4 *Visual Surrey Effort* for a more detailed description of observation and seismic effort.

Ewing Line Changes

When the *Ewing* turned from the end of one survey line to the start of the next, it was necessary to make a very slow and broad turn to avoid possible entanglement of the 6-km long hydrophone streamer towed behind the vessel. Consequently, line changes typically involved several kilometers of steaming, and took ~45 min or longer (up to several hours). Generally, the full array of airguns remained in the water during turns from one line to the next, although the number of guns firing was usually reduced to 16–19 airguns. Operation of the airguns during turns allowed the resumption of geophysical data collection without needing to implement the 30 min observation and ramp-up requirements of the IHA (see Chapter 3 and Appendix A).

Other Types of Airgun Operations

Airguns operated during certain other periods besides periods with production seismic operations and line changes during the SE Caribbean project. Airguns were operated during ramp ups, power downs, periods of equipment repair, testing of the airguns, and from dusk at times when production seismic operations were expected to begin later during the night. Ramp ups involved a systematic increase in the number of guns firing, beginning with the smallest airgun, and adding guns in a sequence such that the source level of the array increased in steps not exceeding 6 dB per 5-minute period. Ramp ups were required by the IHA (see Chapter 3 and Appendix A). Ramp ups occurred in three situations: ***(A)*** During daytime when operations with the 20-airgun array commenced after a period without airgun operations. ***(B)*** During the daytime, after a power down when just one airgun had been firing, i.e., after a marine mammal or sea turtle had been sighted in the "safety zone". ***(C)*** At night when at least 1 airgun, but less than the full airgun array, had been operating prior to darkness. At night, ramp-up procedures differed depending on water depth. Detailed ramp-up procedures are outlined in Chapter 3.

Multibeam Sonar and Sub-bottom Profiler

Aboard the *Ewing*, an Atlas Hydrosweep DS-2 multibeam 15.5-kHz bathymetric sonar, and a 3.5 kHz sub-bottom profiler, operated throughout most of the cruise to map the bathymetry. While the *Ewing* was in the SE Caribbean study area, these sources typically operated simultaneously with the airguns. However, the 15.5 kHz bathymetric sonar was often turned off during OBS lines. In addition, an echo-sounder was operated for safety purposes when the *Ewing* was operating in shallow areas where the water depths were not well charted. These various sonars are described in further detail below.

The *Atlas Hydrosweep* 15.5 kHz multi-beam sonar is mounted on the hull of the *Ewing* (Fig. 2.2), and operates in three modes, depending on the water depth. There is one shallow-water mode and two deep-water modes: an Omni mode and a Rotational Directional Transmission (RDT) mode. When water depth is <400 m, the shallow-water mode is used. The source output is 210 dB re 1 µPa · m rms and a single 1-millisecond pulse or "ping" per second is transmitted, with a beamwidth of 2.67º fore-aft and 90º athwartship. The beamwidth is measured to the –3 dB point, as is usually quoted for sonars. The Omni mode is identical to the shallow-water mode except that the source output is 220 dB re 1 µPa · m. The Omni mode is normally used only during start up. In the RDT mode, each "ping" consists of five successive transmissions, each ensonifying a beam that extends 2.67º fore-aft, and approximately 30º athwartships. The five successive transmissions (segments) sweep from port to starboard with minor overlap, spanning an overall cross-track angular extent of approximately 140º, with tiny (<<1 ms) gaps between the pulses for successive 30º segments. The total duration of the "ping", including all 5 successive segments, varies with water depth but is 1 ms in water depths <500 m and 10 ms in the deepest water.

For each segment, ping duration is 1/5th of these values or 2/5th for a receiver in the overlap area ensonified by two beam segments. The "ping" interval during RDT operations depends on water depth and varies from once per second in <500 m (1640 ft) water depth to once per 15 seconds in the deepest water.

The 3.5 kHz sub-bottom profiler is normally operated from aboard the *Ewing* to provide information about the sedimentary features and the bottom topography that is simultaneously being mapped by the Hydrosweep. The maximum source output (800 watts) of the sub-bottom profiler is 204 dB re 1 μPa, and the normal (500 watts) source output is 200 dB re 1 μPa. The energy from the sub-bottom profiler is directed downward by a 3.5 kHz transducer mounted in the hull of the *Ewing* (Fig. 2.2). The output varies with water depth from 50 watts in shallow water to 800 watts in deep water. Pulse interval is 1 s but a common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause.

In addition, the *Ewing*'s Furuno FGG80 Echosounder was occasionally used to provide additional, more-detailed information on water depths while traversing shallow (<100 m), poorly charted areas for navigational safety purposes. This general type of echosounder is standard equipment for large vessels.

Several standard depth finders and acoustic telemetry gear were used on the *SJII*. A 38 kHz and a 200 kHz depth finder were used continuously throughout the study. In addition, a 12 kHz signal was used to communicate with the OBSs for ~1–2 min for every deployment and recovery, and a 3.5 kHz signal was used for 1–2 min during deployments only.

3. MONITORING AND MITIGATION METHODS

This chapter describes the marine mammal (and sea turtle) monitoring and mitigation measures implemented for L-DEO's SE Caribbean seismic study, addressing the requirements specified in the IHA (Appendix A). The section begins with a brief summary of the monitoring objectives relevant to mitigation for marine mammals. The acoustic measurements and modeling results used to identify the safety radii for marine mammals are then described. The section ends with a detailed description of the marine mammal monitoring and mitigation methods implemented for this cruise from aboard the *Ewing* and *SJII*, and a description of analyses.

The mitigation measures required by the IHA, as received by L-DEO from NMFS on 16 April, differed in some aspects from those specified in the subsequent *Federal Register* notice published by NMFS on 4 May (NMFS 2004). On the evening of 14 May, the MMOs aboard the *Ewing* in the SE Caribbean study area received an e-mail communication requesting that L-DEO implement the mitigation measures as described by NMFS in the *Federal Register*. As a result, the MMOs aboard the *Ewing* and *SJII* implemented the original IHA mitigation measures from 18 April through 14 May, and implemented the updated measures from 15 May through to the end of the cruise on 3 June. The differences between the mitigation measures outlined in the IHA versus the *Federal Register* are identified below.

Monitoring Objectives

The marine mammal and sea turtle monitoring and mitigation objectives were summarized in Chapter 1 (p. 4).

Tasks specific to marine mammal monitoring were as follows (also see Appendix A):

- Provide qualified MMOs for the *Ewing* source vessel and the non-seismic *SJII* support vessel throughout the SE Caribbean Sea seismic survey.
- Aboard the *Ewing* during daytime, visually monitor the occurrence and behavior of marine mammals and sea turtles near the airgun array when the guns are and are not operating. Also monitor visually during specific nighttime events, as identified in the IHA.
- Aboard the *Ewing* during daytime, record (insofar as possible) the effects of the airgun operations and the resulting sounds on marine mammals.
- Aboard the *Ewing* during daytime and nighttime, use the PAM to monitor for vocalizing marine mammals whenever water depths permit, and notify visual observers of nearby marine mammals.
- Aboard the *Ewing*, use the monitoring data as a basis for implementing the required mitigation measures.
- Aboard the *SJII* during daytime, visually monitor the occurrence and behavior of marine mammals and sea turtles, while deploying and retrieving OBSs and while in transit, before and after the *Ewing* operates the airguns in the given area. Also, document any harmed or injured animals potentially associated with the operations.
- Estimate the number of marine mammals potentially exposed to airgun sounds.

Safety and Potential Disturbance Radii

Under current NMFS guidelines, "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which the received pulse levels are ≥180 dB re 1 μPa (rms) for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. Those safety radii are based on an assumption that seismic pulses received at lower received levels are unlikely to injure these mammals or impair their hearing abilities, but that higher received levels might have some such effects. These 180 or 190 dB re 1 μPa levels are measured on a root mean square (rms) basis. The rms (root-mean-square) pressure is an average over the duration of the seismic pulse (Greene 1997; Greene et al. 1998). This is the measure commonly used in studies of marine mammal reactions to airgun sounds. The rms level of a seismic pulse is typically about 10 dB less than its peak level, which in turn is typically about 5 or 6 dB less than the peak-to-peak level (Greene 1997; McCauley et al. 1998, 2000a). Radii at which received levels diminish to 170 and 160 dB re 1 μPa (rms) are considered as possible criteria of behavioral disturbance.

It is not known whether exposure to a sequence of strong pulses of low-frequency underwater sound from marine seismic exploration actually can cause hearing impairment or non-auditory injuries in marine mammals (Richardson et al. 1995:372ff; Finneran et al. 2002). There has been considerable speculation about the potential for injury to marine mammals, based primarily on what is known about hearing impairment to humans and other terrestrial mammals exposed to impulsive low-frequency airborne sounds (e.g., artillery noise). The 180-dB criterion for cetaceans was established by NMFS (1995) based on those considerations, before any data were available on temporary threshold shift (TTS) in marine mammals. NMFS (1995, 2000) concluded that there are unlikely to be any physically-injurious effects on cetaceans exposed to received levels of seismic pulses up to 180 dB re 1 μPa (rms). Finneran has subsequently found that the onset of mild Temporary Threshold Shift (TTS) in a beluga whale (odontocete) exposed to a single watergun pulse occurred at a received level of 226 dB re 1 μPa pk-pk and a total energy flux density of 186 dB re 1 $\mu Pa^2 \cdot s$. The corresponding rms value for TTS onset upon exposure to a single watergun pulse would be intermediate between these values. It is assumed (though data are lacking) that TTS onset would occur at lower received levels if the animals received a series of pulses, especially if these were closely spaced. However, no specific results confirming this are available yet. On the other hand, the levels necessary to cause injury would exceed, by an uncertain degree, the levels eliciting TTS onset.

Radii within which received levels were expected to diminish to various relevant values were determined by L-DEO based on a combination of acoustic modeling and empirical measurements of sounds from a 20-airgun array and various smaller arrays (Table 3.1). The empirical data were collected in the Gulf of Mexico from 27 May to 3 June 2003, with separate measurements in deep and shallow water (Tolstoy et al. 2004a,b). For mitigation purposes during the SE Caribbean study, three strata of water depth were distinguished: deep (>1000 m), intermediate (100–1000 m), and shallow (<100 m).

For ***deep*** water (>1000 m), the maximum distances from the airguns where sound levels of 190, 180, 170, and 160 dB re 1 μPa (rms)[1] might occur are shown in Table 3.1. These estimates are based entirely on an L-DEO propagation model. For deep water, the model was used in lieu of empirical data because the empirical data from deep water of the Gulf of Mexico were limited (Tolstoy et al. 2004a,b). The model estimates were derived for the standard L-DEO 8575-in^3 20-airgun array (Fig. 3.1) and for a single 80 in^3 airgun. (The latter was used during power downs to a single gun for mitigation purposes.) The assumed radii for the 20-gun array are precautionary for two reasons: ***(1)*** No allowance was made for the fact that the

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[1] All levels quoted here are rms (root-mean-square) pressure levels.

TABLE 3.1. Distances (m) to which sound levels ≥190, 180, 170 and 160 dB re 1 μPa (rms) might be received in deep (>1000 m), intermediate-depth (100–1000 m), and shallow (<100 m) water, from the 20-airgun array and from one airgun. These estimates are based on acoustic modeling and (for shallow areas) empirical data from Tolstoy et al. (2004a,b), as applied to a 20-gun 8575 in^3 airgun array. The 180-dB radius is the safety radius applicable to cetaceans, sea turtles and (by implication) sirenians.

Water depth	Array	190 dB	180 dB	170 dB	160 dB
Deep	20 airguns	275	900	2600	9000
(>1000 m)	1 airgun	13	36	110	350
Intermediate	20 airguns	413	1350	3900	10,000
(100–1000 m)	1 airgun	20	54	165	525
Shallow	20 airguns	2000	3500	7000	12,000
(<100 m)	1 airgun	39	108	330	1050

20-airgun array used in the SE Caribbean had a smaller total volume than that used in the modeling (6947 vs. 8575 in^3). ***(2)*** The limited empirical data from deep water indicate that the model used here overestimated the actual radii that applied in deep water (Tolstoy et al. 2004a,b). For both reasons, the radii quoted for deep water very likely overestimate the actual radii at which corresponding received pulse levels would be found. The L-DEO propagation model for the 6947-in^3 20-airgun array is shown in Figure 3.2.

For ***shallow*** water (<100 m deep), the 20-airgun radii in Table 3.1 are the empirical data of Tolstoy et al. (2004a,b) for 160, 170 and 180 dB, and extrapolated to estimate the radius for 190 dB. Tolstoy et al. found that, in the Gulf of Mexico, the radius at which sounds diminished to a given level was considerably larger in shallow than in deep water. To be precautionary, the empirical data were used. Again, no allowance was given to the fact that the 20-airgun airgun array used in this project was in fact slightly smaller than that whose sounds were measured by Tolstoy et al. No empirical data were available for the single 80 in^3 airgun operating in shallow water; its radii in shallow water were assumed to be 3× those calculated by the L-DEO model for deep water.

For ***intermediate*** depth water (100–1000 m), no empirical data were obtained by Tolstoy et al., and the L-DEO model was not entirely appropriate for direct use as it included no allowance for bottom interactions. To be precautionary, the various radii used in intermediate depths were assumed to be 1.5× the values derived from the model for deep water. The radii used for intermediate depths are consistent with those used for all water depths during the L-DEO cruises in 2003, prior to the time when any direct measurements of sounds from the L-DEO airgun arrays were available.

Thus, the 180 dB safety radii around the 20-airgun array were estimated as 900 m (2953 ft), 1350 m (4429 ft), and 3500 m (11,483 ft) for water depths of >1000 m, 100–1000 m, and <100 m, respectively (Table 3.1). These radii correspond to NMFS-designated safety criterion applicable to cetaceans and sea turtles for the SE Caribbean study. Corresponding predicted safety radii around a single 80 in^3 airgun are also shown in Table 3.1.

There were times when the 6947-in^3 20-airgun array was deployed but fewer than 20 guns were firing (e.g., during turns between lines). At these times, the full safety radius for the 20-airgun array (in fact, for the 8575 in^3 array) was assumed to apply, regardless of the number of guns firing. The one exception was any period when only 1 airgun was operating. For determination of shut-down radii in the field and also during data analysis, we differentiated between 1 airgun operating and >1 airgun operating.

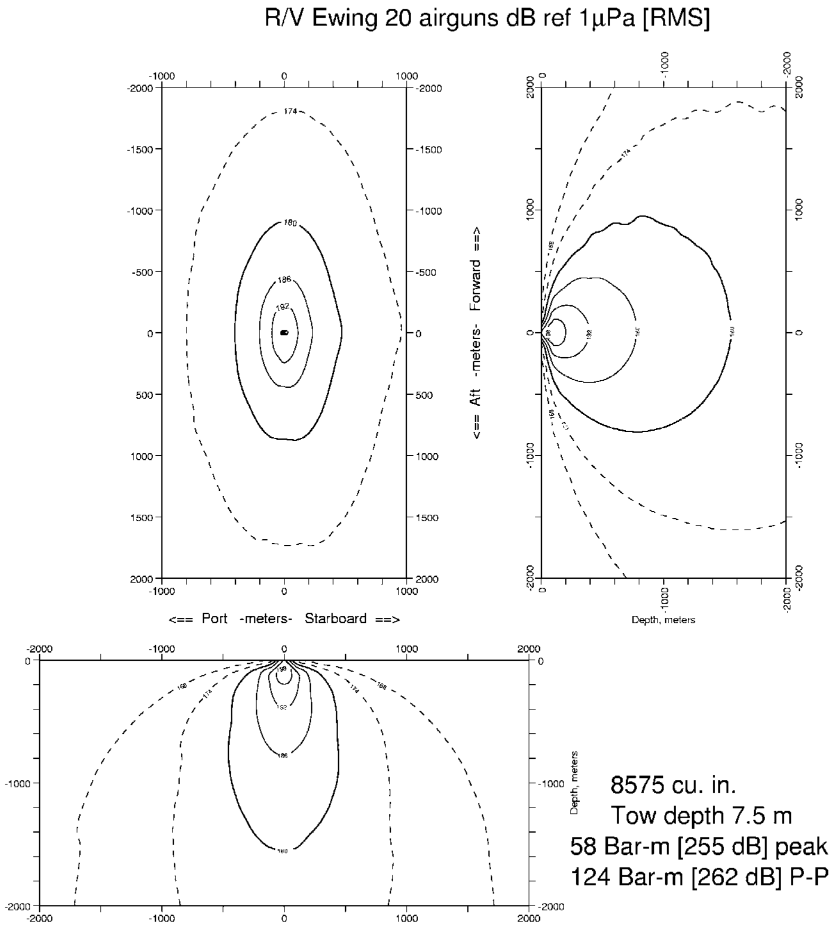

FIGURE 3.1. Predicted received sound levels in deep water from the L-DEO standard 8575-in^3 20-airgun array, which is slightly larger than that used during the SE Caribbean survey during April–May 2004.

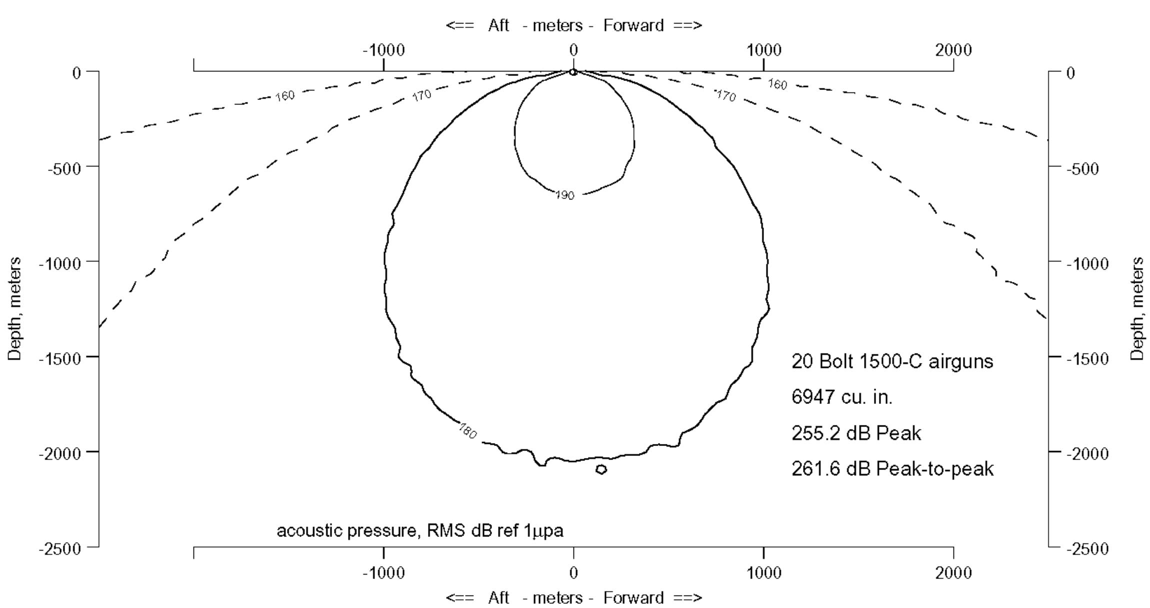

FIGURE 3.2. Predicted received sound levels in deep water (along the fore–aft axis) from the 6947 in^3 20-airgun array used in the SE Caribbean Sea and adjacent Atlantic Ocean during April–May 2004.

Monitoring and Mitigation Requirements Specified by the IHA

This section summarizes the monitoring and mitigation requirements outlined in the IHA issued to L-DEO on 16 April 2004 (Appendix A). As indicated above, on 14 May L-DEO was asked by NMFS to replace some of the mitigation measures identified in the original IHA with those published by NMFS in the *Federal Register* (NMFS 2004) on 4 May. These "updated" mitigation measures are mentioned below in cases where they differed from the IHA requirements. The monitoring methods used during the SE Caribbean seismic study were designed by L-DEO to meet or exceed these requirements.

- At least three biologically-trained on-site observers (i.e., MMOs), approved in advance by NMFS were required to be aboard the *Ewing* source vessel, and two such observers aboard the *SJII*, to visually monitor and document the effects of the seismic surveys and the resulting sounds on marine mammals and turtles. An additional two MMOs aboard the *Ewing* were required to have experience conducting PAM.
- MMOs were required to be provided with and use, as appropriate, NVDs, Big-eye binoculars, and reticle and/or laser rangefinding binoculars, to monitor for marine mammals and sea turtles.
- MMO(s) were required to be on watch whenever the "seismic array" was operating during daylight hours. Where possible, two MMOs were required to be on watch whenever "seismic arrays" were powered up (i.e., ramped up).
- To the extent possible, individual MMOs were to be on watch for continuous periods of 4 hours or less.
- Other crew members were to be instructed to keep watch for marine mammals and turtles. If any were sighted, the crew member was to notify the MMO and, if the mammal was within or closely approaching its designated safety zone, implement the power down or shut down provisions.
- MMOs were required to be on watch for a minimum of 30 minutes prior to the commencement of seismic operations, or any time that power to the airgun array had been reduced for a period of one hour or more.
- Per the IHA, until the evening of 14 May, ramp up was permitted at night from a power down, as long as one 180-dB airgun had been operational. After 14 May, ramp up was permitted at night from a power down only when operating in water >100 m deep AND either no marine mammal calls had been detected via PAM during the entire period of the power down or the entire 180-dB radius was visible.
- After 14 May, if marine mammals were detected during daylight hours, PAM was required to be continued through the succeeding night.
- After 14 May, ramp up from a shut down could not begin during the day unless the entire 180-dB safety radius was visible (i.e., no ramp up could begin in heavy fog or high sea states of Beaufort Force 5 or higher). Ramp up from a power down was still permitted under these conditions.

Visual Monitoring Methods

This section describes the methods of visual monitoring aboard the *Ewing* and the *SJII*, as implemented during the SE Caribbean Sea cruise. Methods used for PAM are described in a separate subsection that follows. Visual monitoring methods were designed to meet the requirements identified in the IHA (see above and Appendix A). The data collected were used to estimate the number of marine mammals potentially affected by the project. They also provided the information needed to implement the mitigation procedures in the field as described below. Results of the monitoring effort are presented in Chapter 4.

Résumés documenting the qualifications of the MMOs were provided to and approved in advance by NMFS prior to commencement of the study. All MMOs participated in a review meeting before the start of the study, designed to familiarize them with the operational procedures and conditions for the SE Caribbean Sea cruise, reporting protocols, and IHA stipulations aboard each vessel. In addition, implementation of the IHA stipulations was explained to the Captain, Science Officer, and/or Science Party principal investigators (PIs) aboard each vessel. MMO duties included

- watching for and identifying marine mammals and sea turtles, and recording their numbers, distances, and behavior;
- noting possible reactions of marine mammals and sea turtles to the seismic operations;
- initiating mitigation measures when appropriate; and
- reporting the results.

The bridge crew aboard each vessel were requested to watch for marine mammals and sea turtles while on duty as part of their normal operations insofar as possible, and to alert the MMOs immediately regarding any sightings.

Visual watches took place from the *Ewing* and the *SJII* in the SE Caribbean study and during transits to and from the study area. The *SJII* provided the opportunity for MMOs aboard the *SJII* to conduct observations for marine mammals and sea turtles incidental to OBS deployment and retrieval, and during transits in the study area, before and after the *Ewing* conducted seismic activities in the same area. Watches by MMOs aboard these two vessels typically began at sunrise and continued until sunset. On each vessel, visual observations were conducted from the flying bridge, which offered the highest vantage point. During inclement weather (e.g., rain), MMOs watched from the bridge of each vessel. Visual observations were centered forward of each vessel, but also included sweeps to the rear of the vessel. One or two observers were typically on visual duty at a time. When two observers were on watch, the focal scan area was generally divided, with one observer concentrating on the area to the left of the bow and the other on the area to the right of the bow.

While on watch, visual observers kept systematic written records of the vessel's position and activity, and environmental conditions. Watch data were entered manually onto a datasheet approximately every 30 min, as activities allowed. Additional data were recorded when marine mammals or sea turtles were observed. For all records, the date and time (in GMT), vessel position (latitude, longitude), and environmental conditions were recorded. Environmental conditions also were recorded whenever they changed, and with each sighting record. Standardized codes were used for the records, and written comments were usually added as well. Data recorded specific to each vessel are described separately below.

For each marine mammal sighting, the following information was recorded: species, number of individuals seen, direction of movement relative to the vessel, vessel position and activity, sighting cue, behavior when first sighted, behavior after initial sighting, heading (relative to vessel), bearing (relative to vessel), distance, behavioral pace, species identification reliability, and environmental conditions. Distances to marine mammal groups were estimated from the MMO station on the flying bridge, rather than from the nominal center of the airgun array. The bearing from the observation vessel to the nearest member of the marine mammal group was estimated using positions on a clock face, with the bow of the vessel taken to be “12 o’clock”, and the stern at 6 o’clock.

The following information was also recorded for other vessels within at least 5 km (as specified in the IHA) at the time of a marine mammal sighting: vessel type, size, heading (relative to study vessel), bearing (relative to study vessel), distance, and activity. Descriptions of the data recorded for each marine mammal sighting are included in Appendix C.

All data were initially recorded on custom paper datasheets in the field, and were entered into a Microsoft Excel® database at the end of the day. The database was constructed to prevent entry of out-of-range values and codes. Data entries were checked manually by comparing listings of the computer-ized data with the original handwritten datasheets, both in the field and upon later analyses. Data collected by the MMOs were also checked against the navigation and shot logs collected automatically by the vessel’s computers, and manually against the geologists’ project logs.

Visual Monitoring Methods Aboard **the** *Ewing*

The primary purpose of MMOs aboard the *Ewing* was to conduct monitoring and implement mitigation measures to minimize and avoid exposure of marine mammals and sea turtles to airgun sounds with received levels ≥180 dB re µPa (rms), and to document any reactions to seismic activities. Visual observers were required to watch for marine mammals and sea turtles during all daytime periods when airguns were firing. In addition, during the daytime, MMOs conducted watches during periods when the source vessel was underway but the airguns were not firing. This included ***(1)*** periods during transit to and from the SE Caribbean study area, ***(2)*** a short “pre-seismic period” while equipment was being deployed, ***(3)*** periods when airguns stopped firing while equipment was being repaired, and ***(4)*** a short “post-seismic” period.

A total of five biologically-trained observers were present on the *Ewing* during seismic operations. Two of these MMOs were also experienced with PAM. All MMOs had prior experience with marine mammal observations, and the lead observer (MS) had over 20 years of experience. One observer (AS), a Venezuelan resident, had several years of field experience with marine mammals in the SE Caribbean study area.

At least one or two MMOs were always present during daytime watches aboard the *Ewing*. Occa-sionally, three or four observers were on watch, particularly when additional assistance was requested during marine mammal sightings. Two observers were present for at least 30 min before as well as during all ramp ups, both day and night. During the day, observations continued after ramp up, but during the night, observations by MMOs ceased after the completion of the ramp up. While in shallow water (<100 m) during the day, two observers were on watch to the greatest extent possible, since the 180 dB safety radius was considerably larger (3500 m) in shallow water compared to deep and intermediate depth waters.

Observations were generally made from the *Ewing*’s flying bridge (Fig. 2.1, 2.3), the highest suitable vantage point on the *Ewing*. The observer's eye level was ~14.5 m (47 ft) above sea level. The flying bridge afforded a view of ~210º centered on the front of the *Ewing*, with partial obstructions to the stern. With two or more observers, one stationed on the port and one on the starboard side of the vessel, the partial obstruction was reduced to some extent. MMOs observed from the *Ewing*'s bridge during periods of poor weather. The observer's eye level on the bridge was ~11.7 m (38 ft) above sea level.

Visual watches aboard the *Ewing* were usually conducted in 1–2 h shifts (maximum 4 h), alternating with PAM shifts and/or 1–4 h breaks, for a total of 9 to 12 h per day per MMO during full operational days. Four-hour shifts usually occurred only when marine mammals were sighted. Observers scanned around the vessel (Fig. 2.3), alternating between unaided eyes and 7×50 Fujinon binoculars. One observer also scanned occasionally with 25×150 Big-eye binoculars, particularly while in shallow (<100 m) water and to identify species or group size during sightings. Both the Fujinon and Big-eye binoculars were equipped with reticles on the ocular lens to measure depression angles relative to the horizon, an indicator of distance. When the Big-eyes were in continuous use, one observer scanned primarily with the Big-eyes while the other observer(s) scanned the full visual arc with the naked eye or Fujinon binoculars.

Ewing bridge personnel were provided with a copy of the observer instruction manual and marine mammal identification guides that were kept on the bridge. If bridge crew sighted marine mammals or sea turtles while the airguns were operating and no MMO was present, they were asked to implement power-down provisions when required. They were given instructions on how to fill out specific marine mammal and sea turtle sighting forms in order to collect pertinent information on any sightings when MMOs were not on active duty (e.g., at night).

At least one MMO was on call at night aboard the *Ewing* in case bridge personnel saw a marine mammal. Nighttime observations by MMOs took place only aboard the *Ewing* and generally only when required, i.e., when a ramp up was to be conducted. Image intensifying Night Vision Devices (NVDs, ITT Industries Night Quest NQ220 "Night Vision Viewer") were used during nighttime observations, although previous experience has shown that marine mammals are rarely detected at night even with the use of such devices. Nonetheless, they do provide some observation capability at close distances at night (see Appendix C *in* Smultea and Holst 2003, Appendix B in Holst 2004, and Appendix D in this report).

Vessel position and information about airgun activity (number and total volume of guns) were available from a monitor on the *Ewing* flying bridge. That monitor was connected to the bridge navigational display monitor. The position of the vessel was automatically logged every minute by the *Ewing*'s navigation system. Those data were used when detailed position information was required.

Intra-ship phone communication with the geophysicists and the MMO conducting PAM (in the ship's dry laboratory) was used to alert the visual MMOs to any changes in operations, and any marine mammals (or sea turtles) detected acoustically. Operational activities that were recorded included the number of guns in use, total volume of the guns in use, and type of airgun activity. Vessel/seismic activities recorded by MMOs aboard the *Ewing* are defined below.

- **Ramp up:** Gradual increase in the number of guns firing, beginning with the smallest gun, and increasing in sequence until the full array is firing.
- **Line shooting:** Shooting along lines identified as data collection lines.
- **Shooting offline:** Shooting guns when offline, generally between lines or during turns.
- **Seismic testing:** Test firing guns; firing pattern tends to be irregular and sporadic.
- **Power down:** A reduction in the number of guns firing from a full array to one gun. Could be due to the presence of a marine mammal or sea turtle within safety radius, or another reason (e.g., gun repair).

- **Shut down:** Immediate cessation of all airgun operations. Most likely due to the presence of a marine mammal or sea turtle within safety radius, but could be for other reasons (e.g., mechanical failure).
- **Other:** No airgun operations. Used to enter environmental conditions, identify when the vessel was in transit, etc.

Visual Monitoring Methods Aboard the SJII

The primary purpose of having MMOs aboard the non-seismic vessel *SJII* was to monitor for any injured animals potentially associated with exposure to strong seismic sounds. This monitoring measure was requested by NMFS in response to comments and concerns submitted in response to the *Federal Register* notice concerning the intent to issue an IHA to L-DEO for the present project. Because a second ship, the *SJII*, was planned to participate in the project for other reasons, it was practical to implement this non-standard procedure during this specific cruise. In addition, MMOs aboard the *SJII* served to document the occurrence and behavior of marine mammals and sea turtles during daylight periods in areas before and after the *Ewing* had conducted seismic operations. This provided a substantial increment of "sightings per unit effort" data that could be compared with corresponding data from the *Ewing* at times when airguns were (and were not) operating. Two MMOs were aboard the *SJII*, with at least one observer on visual watch during daylight periods when underway. MMOs aboard the *SJII* typically alternated 2-h visual watches with 1-h breaks for a total of ~9–10 h per observer each day.

MMOs usually watched from the flying bridge of the *SJII*, where the observer's eye level was ~11.4 m (37 ft) above sea level. The flying bridge afforded a view of nearly 360°. During poor weather conditions, MMOs were stationed on the bridge of the *SJII*; there, the observer's eye level was ~8.5 m (28 ft) above sea level. MMOs scanned the area around the *SJII* for marine mammals and sea turtles, alternating between unaided eyes and 7x50 reticle Fujinon binoculars. The visual search protocol was similar to that used by observers aboard the *Ewing*.

The *SJII*'s position was logged automatically every minute by the onboard navigation system and stored on the ship's network. At the end of every day, the MMOs downloaded the navigation data and filled in the latitude and longitude for every handwritten time entered on the field datasheet. Definitions of ship activities recorded aboard the *SJII* included deployment or recovery of OBSs, when the ship generally stayed in an area at variable speeds of 0–2 kt; transit, while the vessel was underway and traveling at speeds of ~9–10 kt; and anchoring in secluded bays while the scientists worked on the OBSs. MMOs did not maintain an active watch while the *SJII* was anchored in bays or other areas along the coast.

Acoustic Monitoring Methods Aboard the Ewing

Due to the limitations of visual surveys, passive acoustic monitoring was conducted to complement the visual monitoring program. Visual monitoring typically is not effective during periods of bad weather or at night, and even with good visibility, is unable to detect marine mammals when they are below the surface or beyond visual range. Acoustical observations can be used in addition to visual observations to improve detection, identification, localization, and tracking of marine mammals. The acoustical system was monitored in real time so that (in daytime) the visual observers could be advised when marine mammals were detected, as directed in the IHA (Appendix A).

The acoustic monitoring system used was the SEAMAP Cetacean Monitoring System. The SEAMAP system consists of a low-noise, towed hydrophone array, which is connected to the vessel by a "hairy" faired cable, and is deployed by a winch. The array was equipped with four hydrophones, although only two could be monitored at one time with the SEAMAP system. The distance between the outer hydrophones was ~50 m (164 ft), with the center hydrophones placed at frequency thirds. This separation is considered optimal for detecting calls from a wide range of marine mammal species (SEAMAP 2003).

The lead-in of the array was ~300 m (984 ft) long, and the hydrophone array was 56 m (184 ft) long. The system can be ballasted at different depths, but the detection range is slightly reduced if the array is towed at shallow water depths. For example, when towed at a depth of 40 m (131 ft) at 5 kt, the array can detect sperm whale vocalizations out to 5–6 km or 2.7–3.2 n.mi. (SEAMAP 2003). At speeds of 7–8 knots, and towing depths of 8–10 m (26–33 ft), the detection range is reduced to 3–4 km or 1.6–2.2 n.mi. (SEAMAP 2003). Smaller whales with higher frequency vocalizations, such as dolphins, can be detected up to 2 km away. During the SE Caribbean survey, only 240 m (787 ft) of lead-in rope were used, and the array was towed at a depth of ~20 m (65 ft) due to shallow water depths in some parts of the study area.

The signals received by the hydrophone array were routed via a molded deck cable to onboard equipment, where the signals were amplified and processed. The software associated with the SEAMAP system monitors acoustic data, hydrophone depths, and GPS position, and it processes and displays the call data. SEAMAP uses cross-correlation techniques, as applied to the waveforms from two SEAMAP hydrophones, to estimate the bearing to the marine mammal in real-time. The arrival times of the sound energy (in this case, a call) at the two hydrophones and the distance between them, combined with the speed of sound, can be used to determine the bearing to the marine mammal. This information was graphically presented using a map display provided by SEAMAP.

For each bearing, there is also a "mirror-image" complementary bearing on the opposite side of the ship's trackline. When only one call is detected, it is not possible to distinguish reliably, from acoustic data alone, which of the two complementary bearings is the true bearing to the mammal.

When there are successive bearings to repeated calls by the same individual cetacean or group, SEAMAP can theoretically resolve the mirror-image bearing ambiguity and provide information on the distance of the vocalizing cetacean(s) from the hydrophone array. However, in practice, it was generally not possible to localize calling cetaceans based on SEAMAP alone, for a number of reasons:

- SEAMAP notes that the monitoring vessel can make "small" heading changes between successive acoustic "fixes" in order to obtain reliable bearing and distance information on calling marine mammals. This was not possible from the *Ewing* during the cruise. It was important, for the primary purpose of the seismic survey, to maintain the planned straight-line transect. Also, the 6-km streamer limited the *Ewing*'s turning ability to ~5º per minute.
- In spread-out groups of individuals, it is impossible to ascertain whether successive acoustic bearings are to the same animal or subgroup. With widespread groups, successive calls can originate from varying locations. The resultant sequence of bearings does not necessarily provide successive bearings to any one particular animal or subgroup.

While in the study area, the SEAMAP acoustical array was monitored 24 h per day during airgun operations, and during most periods when airguns were off. While in the study area, the array was typically used in combination with visual monitoring during the day, and by itself throughout the night, whether airguns were operational or not. Beginning on 14 May, SEAMAP was required to be used at night if marine mammals had been detected visually during that day and the airguns were operating.

In practice, acoustic monitoring served to alert visual observers when calling cetaceans were in the area. SEAMAP was often capable of detecting calling cetaceans before they were seen by visual observers. This helped to ensure that marine mammals were not nearby when shooting was underway or about to commence. Acoustical observations always began before the start of seismic operations, to help establish (in a relative sense) the presence of calling marine mammals in the area before the ramp up of airguns.

One MMO monitored the SEAMAP acoustic detection system at any one time, by listening to the signals via headphones and/or speakers and watching the map-based database viewer for frequency ranges produced by marine mammals. The system is able to monitor broadband signals from 8 Hz to ~22 kHz. Interference effects occurred from ship noise and airgun sounds, although ship noise appeared to be minimal. Hardware was used that filtered out sounds from airguns as they were fired. This made listening to the received signals more comfortable while using headphones. This filtering procedure filtered out all sounds for ~1–2 s; during this period, no other sounds could be heard. However, it is doubtful that any marine mammal call sequences were missed during airgun shots as the call sequences typically lasted more than 1–2 s. More importantly, the SEAMAP system seemed to have limited ability to detect low frequencies (<100 Hz) such as those typically produced by baleen whales. No baleen whale vocalizations were recorded, although several visual sightings were made.

MMOs monitoring the acoustical data were usually on shift for 1–3 h, with the exception of one person who was usually on duty for 6 h through the night to allow the visual observers to obtain 8 h of sleep. All five MMOs aboard the *Ewing* rotated through the SEAMAP acoustic monitoring position, although the two MMOs most experienced with acoustics were on SEAMAP duty more frequently.

When possible marine mammal vocalizations were detected, the acoustic data were saved using the "grab it" function of the SEAMAP software. This saved the last 2 min of the signal into a .wav file on the hard drive of the computer that runs the SEAMAP software program. When the signal-to-noise ratio of the calling cetaceans was judged to be adequate (moderately strong and clear calls), the SEAMAP software was also used to record ~10 min of continuous recordings that were automatically saved onto the hard drive as described above. In addition, one MMO brought aboard additional recording equipment that was used to obtain continuous longer recordings of cetaceans producing moderate to strong signals.

When cetacean calls were heard during daylight hours, the visual observers on the flying bridge or bridge were immediately notified of the presence of calling marine mammals. Each acoustic "encounter" was assigned a chronological identification number. An acoustic encounter was defined as any calls of a particular species or species-group separated by <1 hr (Manghi et al. 1999). Notes were taken in a hand-written logbook to document the following information associated with the acoustic encounter: the acoustic encounter identification number, whether it was linked with a visual sighting, GMT date, GMT time when first and last heard and whenever any additional information was recorded, GPS position and water depth when first detected, species or species group (e.g., unidentified dolphins, sperm whales), bearings and ranges from the hydrophone array obtained from SEAMAP when possible, types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information. In addition, every 30 min the acoustic MMO on duty noted the presence or absence of cetacean signals. The acoustic MMO also noted the seismic state, vessel activity, and any changes in the numbers of airguns operating from a monitor displaying such information in the acoustic area and notified the MMOs on the flying bridge of these changes via telephone or radio. A separate data sheet was filled out for each acoustic encounter. Written acoustic data were later entered manually into an Excel spreadsheet.

Analyses

For the purposes of analyses, marine mammal sightings made from the *Ewing* source vessel and the *SJII* non-seismic vessel were divided into several types of analysis categories related to vessel and/or seismic activity. The categories used were similar to those used during past L-DEO seismic studies (e.g., Smultea and Holst 2003; MacLean and Haley 2004). Some of these categories were later combined if data within a category were not significantly different or were too sparse for analyses (see Chapter 4). In general, data were categorized as "seismic" or "non-seismic". "Seismic" includes all data collected from the *Ewing* source vessel while the airguns were operating, including ramp ups. Non-seismic includes all *SJII* data, and *Ewing* data obtained before (pre-seismic) or >6 h after (post-seismic) airguns were turned off. Data collected during post-seismic periods from 0 to 6 h after cessation of seismic were considered "recently exposed" (0–2 h) or "potentially exposed" (2–6 h) to seismic and were not included in either the "seismic" or "non-seismic" categories.

The "recently exposed" and "potentially exposed" categories were based on the following logic: The *Ewing* seismic vessel travels at a speed of ~4 kt (or 7.5 km/h) while conducting seismic operations. Thus, in 2 h, the vessel travels ~15 km, or about the maximum distance where cetaceans have generally seemed to be affected by acoustic stimuli (other than the displacement effect seen in bowheads; see review in LGL Ltd. 2003a,b). After traveling 2 h away from the last seismic shot, the vessel would be in an area where the distribution of animals is not likely to be influenced by the earlier seismic sounds; however, the animals presumably would have heard the seismic sounds. In 6 h, the vessel travels ~45 km, which is beyond the distance where earlier sounds might have caused appreciable changes in distribution, behavior, or sighting rates (given what is known about effects of seismic surveys on marine mammals). Even at 45 km, marine mammals might have heard earlier sounds, but they are unlikely to have changed their behavior or distribution much (if at all), and 6 h would have passed since that time anyway.

Marine mammal sightings during the "seismic" and "non-seismic" periods were used to calculate sighting rates (#/km), which were used to calculate the corresponding densities (#/km^2) of marine mammals near the survey ships during seismic and non-seismic periods. These calculations were based on line transect principles (Buckland et al. 2001). Densities during non-seismic periods were used to estimate the numbers of animals that would have been present near the seismic operation in the absence of seismic. Densities during seismic periods were used to estimate the numbers of animals present near the seismic operation and exposed to various sound levels. The difference between the two estimates could be taken as an estimate of the number of animals that moved away from or avoided the operating seismic vessel (or that changed their behavior sufficiently to be missed by visual observers).

Densities were corrected for

- $g(0)$, a measure of detection bias. This factor allows for the fact that less than 100% of the animals present along the trackline are detected.
- $f(0)$, the reduced probability of detecting an animal with increasing distance from the trackline.

The $g(0)$ and $f(0)$ factors used in this study were taken from results of previous work, not from observations made during this study. Sighting rates during the present study were either too small or, at most, marginal to provide meaningful data on $f(0)$ based on group size. In particular, sample sizes were too small for sperm whale, Bryde's whale, short-finned pilot whale, and unidentified whale, and marginal for the most common species groups (dolphins). Also, this type of project cannot provide data on $g(0)$. Estimates of these correction factors were taken from Koski et al. (1998) and Barlow (1999) for corresponding species and sea states. Marine mammal sightings were subjected to species-specific truncation criteria as used in the above-cited analyses of marine mammal sightings. Only the survey effort and marine mammal sightings obtained with Beaufort Force ≤5 were used for analysis. No sightings were made of cryptic species such as beaked whales; analyses for those species generally consider only the sightings and effort during Beaufort Force ≤2.

For purposes of the IHA, any marine mammal that might have been exposed to airgun pulses with received sound levels ≥160 dB re 1 µPa (rms) was assumed to have been potentially disturbed. The sound level received from the 20-airgun system was assumed to be ≥160 dB re 1 µPa at estimated distances out to 12, 10 and 9 km at water depths of 0–100, 100–1000 m, and >1000 m, respectively. These distances are from Table 3.1, and are subject to the considerations discussed there. All of these distances are probably somewhat overestimated given that the total volume of the actual airgun array (6947 in^3) was slightly less than assumed in deriving Table 3.1 (8575 in^3). Also, the 9 km figure for water depths >1000 m does not allow for the smaller 160-dB radius measured for deep water by Tolstoy et al. (2004a,b).

Estimates of the numbers of potential exposures of marine mammals to sound levels ≥160 dB re 1 µPa (rms) were calculated by multiplying three values for the 20-airgun source:

- the number of kilometers of seismic survey using the 20-airgun array,
- the width of the area assumed to be ensonified to ≥160 dB (2 × 160 dB radius), stratifying based on three different water depth ranges (see Table 3.1), and
- the "corrected" densities of marine mammals estimated by line transect methods as summarized above.

The estimated number of individual exposures to levels ≥160 dB obtained by multiplying these three values is likely to overestimate the number of different individual mammals exposed to the airgun noise at received levels ≥160 dB. This occurs because some exposure incidents are likely to involve the same individuals previously exposed, given the fact that parts of some seismic lines were surveyed more than once, and some lines approached close to other lines (see Fig. 4.1, 4.2, later).

A minimum estimate of the number of different individual marine mammals potentially exposed (one or more times) to ≥160 dB re 1 µPa (rms) was calculated. This involved multiplying the corrected density of marine mammals by the area exposed to ≥160 dB one or more times during the course of the study. This area was calculated using MapInfo GIS software by creating a "buffer" that extended on both sides of the vessel's trackline to the predicted 160 dB radius. Because the 160-dB radius varied with water depth (see Table 3.1), the width of the buffer also varied with water depth. The buffer includes areas that were exposed to airgun sounds ≥160 dB multiple times (as a result of repeated or tracklines close enough for their 160 dB zones to overlap). The buffer area only counts the repeated-coverage areas once, as opposed to the exposure method outlined above. The calculated number of different individual marine mammals exposed to ≥160 dB re 1 µPa (rms) is considered a minimum estimate because it does not account for the movement of marine mammals during the course of the study.

The above process was repeated for delphinids using the 170 dB radius (see Table 3.1) to estimate the number of exposures and the number of individuals exposed to seismic sounds ≥170 dB re 1 µPa (rms). The process was also repeated using the 180 dB radius for all species to estimate the numbers of animals that would have been subjected to sounds ≥180 dB re 1 µPa (rms) if they had not altered their course to avoid those sound levels.

There were brief periods during ramp up when <20 airguns were operated and periods after power downs when a single airgun was operated. We conservatively included all periods when >1 airgun was firing in the calculations of numbers of animals exposed to the full 20-gun array. We separately calculated the numbers of animals exposed to sounds ≥160 and ≥180 dB and the numbers of delphinids exposed to sounds ≥170 dB during operations of the single airgun.

Mitigation Measures as Implemented

This section identifies and describes the mitigation measures that were implemented during the SE Caribbean cruise. Mitigation included those measures specifically identified in the IHA dated 16 April (see Appendix A) and those measures later identified by NMFS in the *Federal Register* (NMFS 2004) and implemented after 14 May. Additional mitigation measures were built into the design of the project, as identified in Section XI of L-DEO's IHA application (LGL Ltd. 2003a). Mitigation measures implemented during the study included the following:

- The volume of the 20-airgun array used during the SE Caribbean cruise was smaller (6947 in^3) than the "standard" 20-airgun array (8575 in^3) typically operated from the *Ewing* (*cf*. Fig. 2.4; Tolstoy et al. 2004a,b). This smaller volume was judged to be the smallest array size that could be used while still meeting the scientific objectives of the geophysicists conducting the SE Caribbean study. This smaller volume slightly reduced the sound level produced by the airguns, and thus the potential exposure of marine mammals to airgun sounds. The sound pressure produced by an airgun array generally varies as a function of the cube root of total array volume when other factors (such as the total number of airguns) are held constant (Caldwell and Dragoset 2000).
- The configuration of the array directed more sound energy downward, and to some extent fore and aft, than to the side of the track. This reduced the exposure of marine mammals, especially to the side of the track, to airgun sounds.
- Safety radii implemented for the SE Caribbean cruise varied with water depth based on results of the acoustic calibration study conducted from the *Ewing* in the Gulf of Mexico in 2003 (Tolstoy et al. 2004a,b), as discussed earlier in this chapter.
- A change in vessel course and/or speed alteration was identified as a potential mitigation measure if a marine mammal was detected outside the safety radius and, based on its position and motion relative to the ship track, was judged likely to enter the safety radius. However substantial alteration of vessel course or speed was not feasible during the SE Caribbean cruise given the length (6 km) of the streamer being towed. Power downs or shut downs were the preferred mitigation measure when marine mammals were sighted within or about to enter the safety radii.
- Ramp-up procedures were implemented whenever the 20-airgun array was powered up, to gradually increase the source level of the airgun sound at a rate no greater than 6 dB per 5 minutes.
- Power-down or shut-down procedures were implemented when a marine mammal was sighted in or near the applicable safety radius while the airguns were operating.

New mitigation measures implemented for the first time during this cruise included the following:

- Power-down or shut-down procedures were implemented when a turtle was sighted in or near the applicable safety radius while the airguns were operating.
- Ramp up was permitted at night from a power down only when operating in water >100 m deep AND either no marine mammal vocalizations had been detected via PAM during the entire period of the power down, OR the entire 180-dB radius was visible. Given the rather large 180 dB radii

associated with the 20-gun array (particularly in shallow water), and the limitations of NVDs, this meant that the entire 180 dB radii were never visible at night.

- If marine mammals were detected during daylight hours, PAM was required to be continued through the succeeding night.
- Ramp up could not begin during the day from a shut down unless the entire 180-dB safety radius was visible (i.e., no ramp up could begin in heavy fog or high sea states of Beaufort Force 5 or higher).

Ramp-up, power-down, and shut-down procedures implemented in the SE Caribbean study area are described in detail below.

Flow diagrams (Fig. 3.3, 3.4) were designed to help the MMOs and other shipboard personnel decide what type of mitigation was required when a marine mammal was sighted during daytime or nighttime operations. These "decision trees" were distributed and explained to the Captain and Science Officer on the *Ewing*, the Principal Investigators, and all scientists before the commencement of seismic activities. Notification procedures were altered slightly after consultation with bridge and scientific personnel. These procedures were modified beginning 14 May after NMFS identified additional mitigation measures not previously identified in the IHA, as noted earlier.

Ramp-up Procedures

A "ramp-up" procedure was followed at the commencement of seismic operations with the 20-airgun array, and anytime after the array was powered down or shut down for a specified duration. Ramp up was not required at the onset of operation of one or two airguns (total volume 80–160 in^3). Under normal operational conditions (vessel speed 4–5 kt), a ramp up was conducted after a shut down or power down lasting 8 min or longer. When the vessel speed was <4 kt, ramp up was conducted after a shut down or power down of 10 min or longer.

The IHA required that, during the daytime, the entire safety radius be visible (i.e., not obscured by fog, etc.), and monitored, for 30 min prior to and during ramp up. The ramp up could only commence if no marine mammals or sea turtles were detected within the safety radius during this period. Throughout the ramp ups, the safety zone was taken to be that appropriate for the entire 20-airgun array and the water depth at the time, even though fewer than 20 airguns were firing until the ramp up was completed.

Per the IHA issued 16 April (Appendix A), ramp ups of the 20-airgun array were only permitted at night when one or more airguns had been operating since sunset. It was assumed that the airgun operations would encourage marine mammals to avoid close approach to the source vessel, reducing the chance that a mammal would be nearby as the airgun array was ramped up. After 14 May, nighttime ramp up was allowed only in water depths >100 m. The rationale was that the large safety radius (3500 m) in water <100 m deep extended too far from the vessel to allow effective monitoring by visual means at night. Furthermore, after 14 May, nighttime ramp up in water >100 m deep was allowed only if PAM was in use and no marine mammal vocalizations had been detected during the entire period of the power down. A further condition for beginning a ramp up at night was that two trained observers using night vision devices (NVDs) had been on watch for at least 30 min prior to the ramp up without seeing any marine mammals or sea turtles. During the day, ramp up from a shut down was only possible if the entire safety zone was visible (i.e., no fog and Beaufort Force <5). The two MMOs continued observations during the ramp up, and the ramp up was to be suspended if marine mammals were detected within the safety radius. It was recognized that the NVDs used aboard the *Ewing* probably have limited utility and may be useful only within ~100–200 m distance, based on "ground-truthing" experiments (Smultea and Holst 2003; Holst 2004; Appendix D of this report).

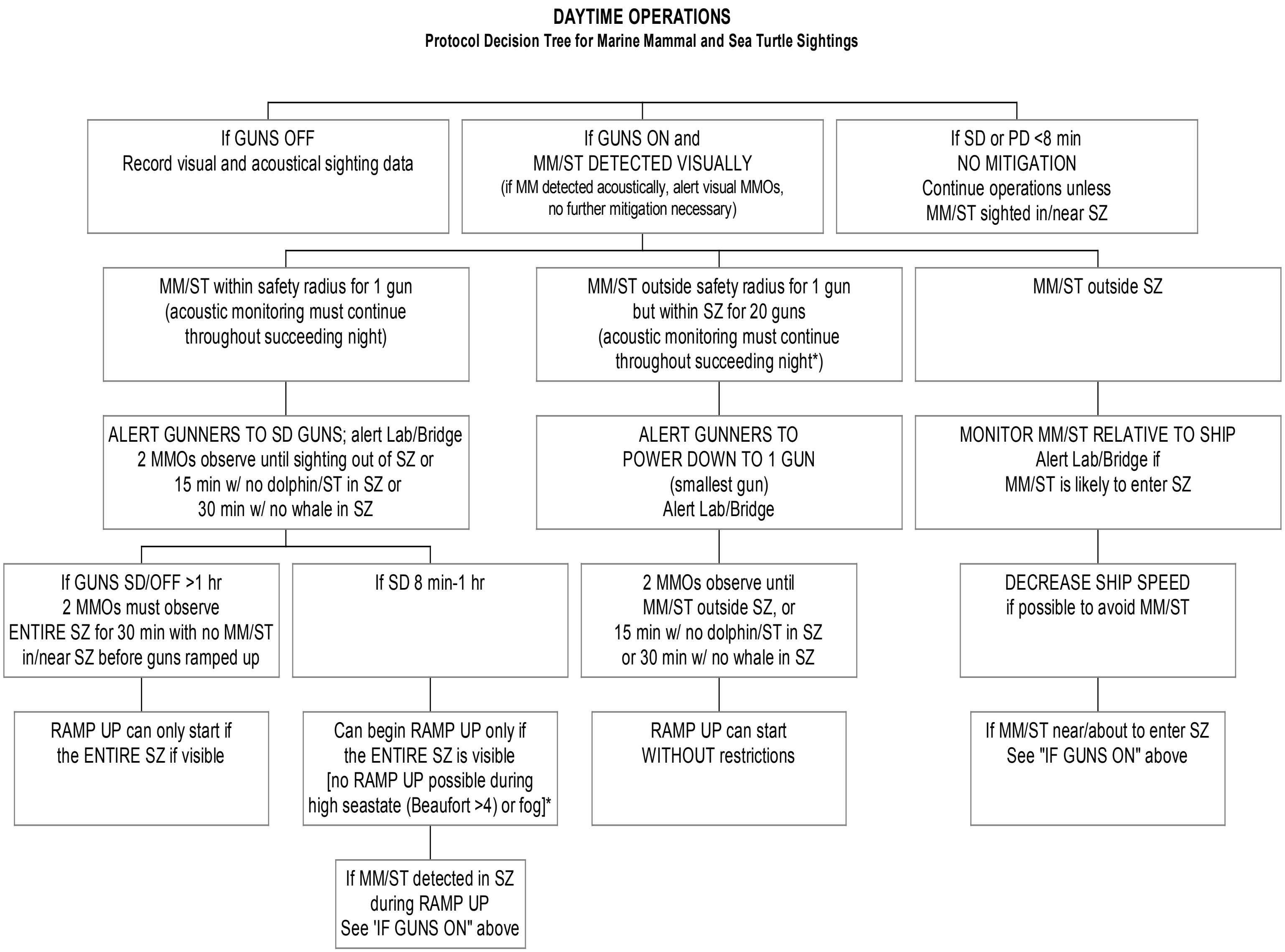

FIGURE 3.3. Flow diagram to aid in implementing ***daytime*** mitigation and monitoring required by the IHA for the April–June SE Caribbean Sea seismic study. MM = marine mammal, ST = sea turtle, SD = shut down, PD = power down, SZ = safety zone. *indicates new mitigation measure.

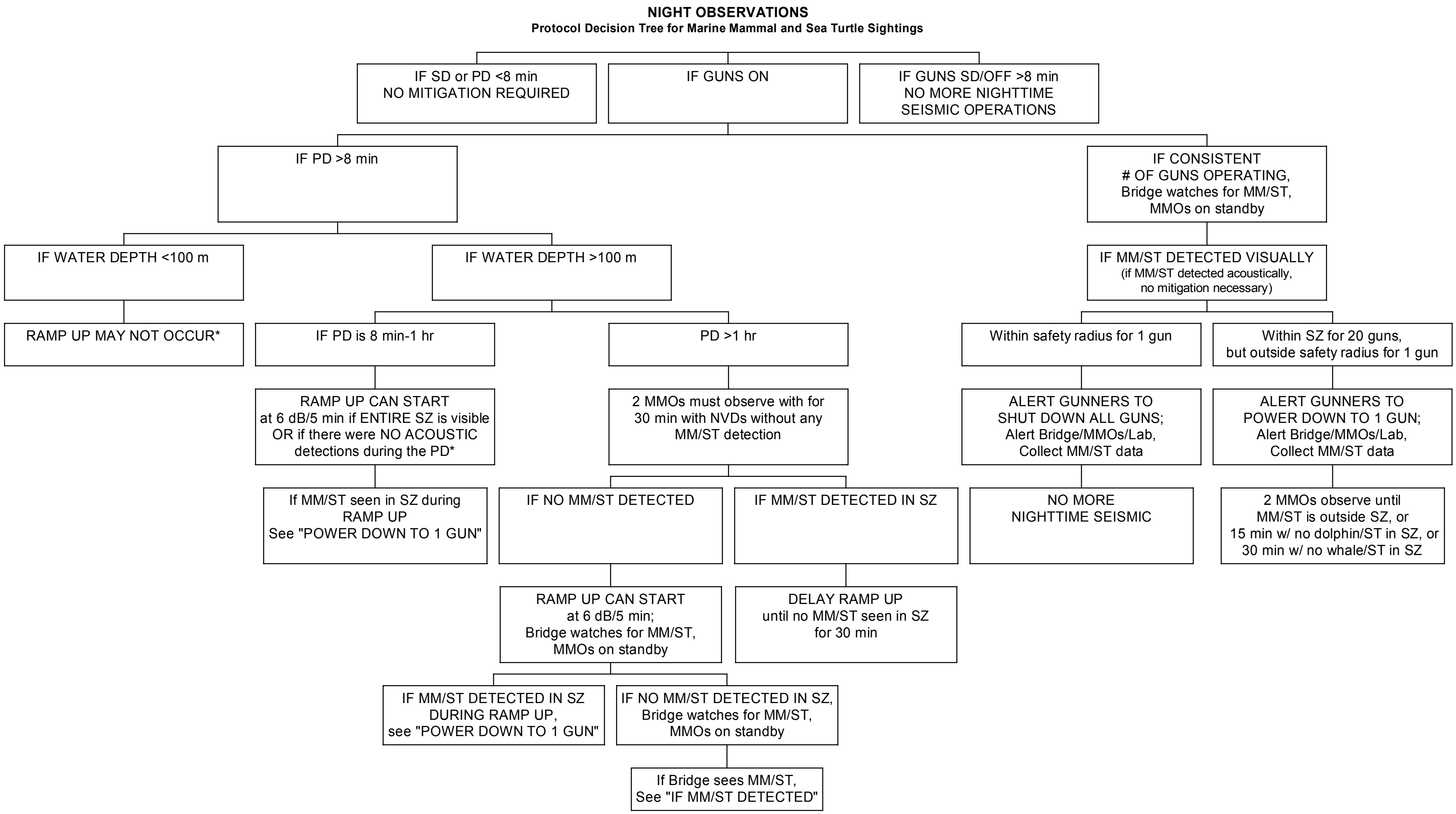

FIGURE 3.4. Flow diagram to aid in implementing ***nighttime*** mitigation and monitoring required by the IHA for the April–June SE Caribbean Sea seismic study. MM = marine mammal, ST = sea turtle, SD = shut down, PD = power down, SZ = safety zone, NVD = night vision devise. *indicates new mitigation measure.

When no airguns were firing at the start of the ramp up, ramp up of the 20-airgun array began with the smallest gun in the array (80 in^3). Airguns were added in a sequence such that the source level of the array (as estimated by L-DEO) would increase in steps not exceeding 6 dB per 5-min period. General ramp-up timing is shown in Table 3.2. For example, full ramp up to the 20-airgun array following the "6 dB per 5-min period" stipulation required ~25 min.

TABLE 3.2. Steps in L-DEO's ramp-up process for the 20-airgun array.

Time (min)	0 min	5 min	10 min	15 min	20 min	25 min
Number of guns operating	1 gun	2 guns	3 guns	6 guns	12 guns	20 guns

Power-down and Shut-down Procedures

Airgun operations were immediately shut down entirely, or powered down to a single operational gun (80 in^3), when one or more marine mammals or sea turtles were detected within, or about to enter, the 180-dB safety radius. This radius depended on the water depth at the *Ewing*'s location (see Table 3.1).

The power-down procedure was to be accomplished within several seconds (or a "one-shot" period) of the determination that a marine mammal or sea turtle was within or about to enter the safety radius. Airgun operations were not to resume until the animal was outside the safety radius, or had not been seen for 15 or 30 min, depending on the type of animal. The 15 min period applied to small odonto-cetes and sea turtles whereas the 30 min period applied to baleen, sperm, or beaked whales. Once the safety radius was judged to be clear of marine mammals or sea turtles based on those criteria, the MMOs advised the airgun operators and geophysicists, who advised the bridge that seismic surveys could re-commence, and ramp up was initiated.

In contrast to a power down, a shut down refers to the complete cessation of firing by all airguns. If a marine mammal was seen within the designated safety radius around the one airgun in operation during a power down (Table 3.1), a complete shut down was necessary.

When a marine mammal was detected within the appropriate safety radius, the airgun operators were immediately notified to power down or shut down the airguns. It typically takes several seconds after a sighting is made before airgun operations can be suspended. Generally, there were no shots, or no more than one shot, between the time a marine mammal or sea turtle was seen and the time when the power down or shut down took effect.

The *Ewing* observers were located on the flying bridge or bridge about 87 m ahead of the airgun array. Thus, the decision to initiate a power down was based on the distance from the observers rather than from the array, unless the animals were sighted close to or behind the array. This was another precautionary measure, given that most sightings are ahead of the vessel.

4. MARINE MAMMALS

Introduction

This chapter provides background information on the occurrence of marine mammals in the project area, and describes the results of the marine mammal visual and acoustic monitoring programs aboard the *Ewing* and *SJII*. In addition, the number of marine mammals potentially affected during project operations is estimated. The monitoring program also included observations for sea turtles, discussed in Chapter 5. L-DEO's SE Caribbean monitoring program represents the largest marine mammal survey effort undertaken to date in the SE Caribbean Sea. Over 900 h and >10,000 km of visual observation effort, and >800 h and >7300 km of acoustic monitoring effort, were conducted. The project has provided, for the first time, survey data on the occurrence of cetaceans across a wide span of longitudes during spring. In particular, prior to this effort, no surveys had been undertaken in the SE Caribbean Sea west of ~68ºW (A. Sayegh, CIC, Margarita Island, Venezuela, April 2004, pers. comm.).

Studies on marine mammals inhabiting the Caribbean have been scarce (Jefferson and Lynn 1994), and abundance in the area is mostly unknown (Roden and Mullin 2000). Romero et al. (2001) noted that knowledge about Venezuela's marine mammals is limited because of limited interest and an absence of an organized whaling industry. However, local shore-based whaling is still an essential part of life for some parts of the Caribbean, such as Grenada, Dominica, St. Lucia, St. Vincent, and the Grenadines (WCW 2004). Those areas are generally north of the region where the seismic survey occurred (Fig. 4.1, later).

Prior to L-DEO's 2004 SE Caribbean seismic study, the most extensive systematic ship-based survey undertaken in the SE Caribbean, including parts of the project area, was by Swartz and Burks (2000); see Swartz et al. (2001, 2003). That study occurred during winter 2000 and employed both visual and passive acoustic survey methods, focusing on the seasonally-occurring humpback whale. In addition, the Centro do Investigación de Cetacéos (CIC) of Venezuela has been conducting systematic and opportunistic vessel surveys for cetaceans in the eastern region of the SE Caribbean project area near Islas de Margarita since 2001 (A. Sayegh, CIC, pers. comm.). CIC has also collated a database on marine mammal strandings throughout the SE Caribbean since 2000 (CIC unpubl. data). One of the MMOs aboard the *Ewing* during this cruise (AS) was the Eastern Regional Coordinator of CIC, and he was familiar with the distribution and occurrence of marine mammals in Venezuela. Data collected by CIC are being prepared for publication, but several reports have already been produced (Balladares et al. 2001; Bermúdez and Oviedo 2001). The following section presents only a general outline of marine mammal distribution in the SE Caribbean Sea, since quantitative data for this area are mostly unavailable.

The marine mammals that may occur in the proposed survey area belong to three taxonomic groups: the odontocetes (toothed cetaceans, such as dolphins and sperm whale), mysticetes (baleen whales), and sirenians (West Indian manatee). A total of 28 cetacean species and the West Indian manatee have been identified as inhabiting or potentially occurring in the project area or SE Caribbean Sea (Table 4.1). No species of pinnipeds are known to occur regularly in the region now. However, vagrant hooded seals have been seen in the Caribbean (see Rice 1998; Mignucci-Giannoni and Odell 2001; Reeves et al. 2002). The Caribbean monk seal (*Monachus tropicalis*) is believed to be extinct, as the last confirmed sighting of this species was made in the 1950s (Debrot 2000; Mignucci-Giannoni and Odell 2001; Reeves et al. 2002). Romero et al. (2001) and the CIC (unpubl. data) noted that at least 25 cetacean species occur in the waters of Venezuela, including freshwater, estuarine, and marine species. Two additional species may occur in Venezuelan waters, but have not been confirmed to do so: the minke and pygmy sperm whale. Since the

TABLE 4.1. The occurrence, abundance, and habitat of marine mammals that are known to or could occur in the seismic survey area of the SE Caribbean Sea and adjacent Atlantic Ocean.

Species	Best Abundance Estimate (CV)[1]	Occurrence[2]	Season[3]	Habitat
Odontocetes				
Sperm whale (*Physeter macrocephalus*)	13,190[a]	Eastern Venezuela, Greater & Lesser Antilles	Summer	Usually pelagic and deep seas
Pygmy sperm whale (*Kogia breviceps*)	536 (0.45)[b]	*	No evidence of seasonality	Deeper waters off the shelf
Dwarf sperm whale (*Kogia sima*)	N.A.	*	No evidence of seasonality	Deeper waters off the shelf
Cuvier's beaked whale (*Ziphius cavirostris*)	3196 (0.34)[c]	Widespread	Summer-Fall	Pelagic
Gervais' beaked whale (*Mesoplodon europaeus*)	N.A.	Greater Antilles, Leeward Islands, Trinidad and Tobago*	Spring-Summer[†]	Pelagic
Blainville's beaked whale (*Mesoplodon densirostris*)	N.A.	Greater Antilles*	No evidence of seasonality	Pelagic
Rough-toothed dolphin (*Steno bredanensis*)	852 (0.31)[d]	Eastern Venezuela, Greater & Lesser Antilles, Columbia	N.A.	Tropical, Oceanic
Tucuxi (*Sotalia fluviatilis*)	N.A.	Along the Coast from Nicaragua to Brazil, Orinoco & Amazon rivers	Year-round	Freshwater and coastal waters
Bottlenose dolphin (*Tursiops truncatus*)	50,092[e]	Widespread	Spring-Summer	Continental shelf, coastal and offshore
Pantropical spotted dolphin (*Stenella attenuata*)	13,117 (0.56)	Eastern Venezuela, Lesser & Netherlands Antilles, Colombia	N.A.	Coastal and pelagic
Atlantic spotted dolphin (*Stenella frontalis*)	52,279[f]	Widespread	Year-round	Mainly coastal waters
Spinner dolphin (*Stenella longirostris*)	N.A.	Eastern-Central Venezuela, Greater & Lesser Antilles	Year-round	Coastal and pelagic
Clymene dolphin (*Stenella clymene*)	5571 (0.37)[d]	Eastern Venezuela, Lesser & Netherlands Antilles	N.A.	Tropical, Oceanic
Striped dolphin (*Stenella coeruleoalba*)	61,540 (0.40)	Venezuelan Islands, Greater & Lesser Antilles, Netherlands Antilles, Colombia	Spring-Summer	Off the continental shelf
Long-beaked common dolphin (*Delphinus capensis*)	N.A.	Eastern Venezuela	Year-round	Coastal
Fraser's dolphin (*Lagenodelphis hosei*)	127 (0.90)[d]	*	No evidence of seasonality	Water >1000 m deep
Risso's dolphin (*Grampus griseus*)	29,110 (0.29)	Central Venezuela, Greater & Lesser Antilles, Colombia	N.A.	Waters 400-1000 m deep
Melon-headed whale (*Peponocephala electra*)	3965 (0.39)[d]	Leeward Islands, Netherlands Antilles*	N.A.	Tropical, Oceanic
Pygmy killer whale (*Feresa attenuata*)	6[g] 518 (0.81)[d]	Western Venezuela, Greater & Lesser Antilles	N.A.	Tropical, Oceanic

Species	Best Abundance Estimate (CV)[1]	Occurrence[2]	Season[3]	Habitat
False killer whale (*Pseudorca crassidens*)	381 (0.62)[d]	Central Venezuela, Greater & Lesser Antilles	Spring-Summer	Tropical, Temperate, Pelagic
Killer whale (*Orcinus orca*)	277 (0.42)[d] 6,600[h]	Widespread	Year-round	Widely distributed
Short-finned pilot whale (*Globicephala macrorhynchus*)	792,524[i]	Eastern Venezuela, Greater & Lesser Antilles, Netherlands Antilles	Year-round[†]	Mostly pelagic
Mysticetes				
Humpback whale (*Megaptera novaeangliae*)	11,570 (0.069)[j] 10,600[k] 10,000[l]	Central-Eastern Venezuela, Greater & Lesser Antilles	Fall-Winter	Mainly near-shore waters & banks except during migration
Minke whale (*Balaenoptera acutorostrata*)	4018 (0.16)[m] 149,000[n]	Greater Antilles, Leeward Islands*	Probably winter	Coastal waters
Bryde's whale (*Balaenoptera edeni*)	35 (1.10)[d]	Eastern Venezuela, Greater & Lesser Antilles, Colombia	Year-round	Pelagic and coastal
Sei whale (*Balaenoptera borealis*)	12-13,000[o]	Eastern Venezuela, Greater Antilles	N.A.	Primarily offshore, pelagic
Fin whale (*Balaenoptera physalus*)	2814 (0.21) 47,300[n]	Venezuela, Greater & Lesser Antilles, Colombia	N.A.	Continental slope, mostly pelagic
Blue whale (*Balaenoptera musculus)*	308[p]	Likely to occur in Venezuela, Colombia*	Probably winter	Shelf, and oceanic waters
Sirenian				
West Indian manatee (*Trichechus manatus manatus*)	86[q] 340[r]	Greater Antilles, Eastern Venezuela, Trinidad and Tobago, Colombia	N.A.	Freshwater and coastal waters

N.A. = Information not available.
[1] Abundance estimates are given for U.S. Western North Atlantic stocks (Waring et al. 2003) unless noted otherwise; CV (coefficient of variation) is a measure of a number's uncertainty or variability on a proportional basis
[2] Based on Romero et al. (2001), Rosario-Delestre (1999); Waring et al. (2003).
[3] From Romero et al. (2001); caution required as seasonal distribution may reflect gaps in reporting.
[a] *g*(o) corrected total estimate for the Northeast Atlantic, Faroes-Iceland, and the U.S. east coast (Whitehead 2002).
[b] This estimate is for *Kogia* sp.
[c] This estimate is for *Mesoplodon* and *Ziphius* spp.
[d] This estimate is for the northern Gulf of Mexico.
[e] Abundance estimate is a total for the Western North Atlantic offshore and coastal stock.
[f] Abundance estimate for the Western North Atlantic offshore and coastal stocks combined.
[g] Based on a single sighting.
[h] Estimate for Icelandic and Faroese waters (Reyes 1991).
[i] This is a combined estimate for *Globicephala sp.* for the Northeast Atlantic (Buckland et al. 1993) and for the Western North Atlantic stock (Waring et al. 2003).
[j] This estimate is for the entire North Atlantic (Stevick et al. 2001, 2003).
[k] Estimate for the entire North Atlantic (Smith et al. 1999).
[l] Estimate for the Southern Hemisphere (IWC 2004).
[m] This estimate is for the Canadian East Coast stock.
[n] Estimate is for the North Atlantic (IWC 2004).
[o] Abundance estimate for the North Atlantic (Cattanach et al. 1993).
[p] Minimum abundance estimate.
[q] Antillean Stock in Puerto Rico only.
[r] Antillean Stock in Belize (Reeves et al. 2002).
* Occurrence in the study area is uncertain, although minke and melon-headed whales are likely to occur.
[†] From Debrot et al. (1998).

present project was limited to marine waters, the freshwater boto (*Inia geoffrensis*), which inhabits the inland rivers of Venezuela, was not considered.

The abundance, occurrence and habitat of each marine mammal species that may occur in the project area are shown in Table 4.1, and the conservation status of each marine mammal species is presented in Appendix E.

The densities of marine mammals in the SE Caribbean study area, as estimated from information available prior to the present project, are shown in Table 4.2. These numbers are based on data reported by Swartz et al. (2002). They are corrected for detectability biases using *f*(0) and *g*(0) values from Koski et al. (1998) and Barlow (1999), unless otherwise noted.

Monitoring Effort and Cetacean Encounter Results

This section summarizes the visual monitoring effort and sightings as well as the acoustic monitoring effort conducted from the *Ewing* and *SJII* during the SE Caribbean seismic study from 18 April to 3 June 2004. Effort and sightings during the brief periods of transit between the port of San Juan, Puerto Rico, and the SE Caribbean study area are also discussed. Acoustic detections from the *Ewing* are discussed separately in the next section. For analysis purposes, visual (and acoustic) observation effort aboard the *Ewing* and *SJII* was divided into a number of categories corresponding to various periods with and without airguns firing. This was done to facilitate evaluation of potential effects of the seismic operations on the apparent density, distribution, and behavior of cetaceans. Categories were later combined if no detectable differences were found, or if sample sizes were too small to allow valid comparisons. These categories were described in Chapter 3 "Analyses".

Visual Survey Effort

Vessel survey tracks of the *Ewing* and *SJII* are plotted in Figures 4.1 and 4.2 by observation effort or seismic activity (airguns on or off). Visual survey effort, in hours of observation and kilometers traveled, is summarized by vessel, airgun activity, and Beaufort Wind Force in Appendices F.1–F.2 (see also Table ES.1 in "Executive Summary"). Aboard the *Ewing*, a total of 510 h of visual observations, representing 4920 km of vessel track, were made in the study area and during transit to/from Puerto Rico from 18 April to 3 June. Appendix F.2 includes all times, day and night, when visual observers were on watch aboard the *Ewing*. Also included are 85 h (1258 km) when observers were on watch during transit to and from the survey area. Of the 510 h and 4920 km of visual observation effort, 6 h and 52 km occurred during nighttime ramp up while the airguns were on. One observer was on visual watch aboard the *Ewing* during 288 h (2787 km), with at least two observers on watch during the remaining 222 h (2133 km). MMOs observed primarily from the *Ewing* flying bridge (492 h, 4764 km), with 18 h and 156 km of observations from the bridge.

Aboard the *SJII*, a total of 394 h of visual observations, representing 5087 km of vessel track, were made in the SE Caribbean and adjacent North Atlantic study area from 19 April to 2 June. This total includes 43 h and 813 km during transit to and from Puerto Rico (Appendix F.1). All visual observations from the *SJII* were during daytime. One observer was on visual watch aboard the *SJII* during 240 h (3078 km), with two or more observers on watch during the remaining 154 h (2009 km). *SJII* MMOs observed primarily from the flying bridge (331 h, 4192 km), with 63 h and 895 km of observations from the bridge.

Beaufort Wind Force during observations on both the *Ewing* and *SJ2* ranged from 1 to 7 (Appendix F.1). Most (38%) of the 510 h of observation effort aboard the *Ewing* occurred with Beaufort Force 5 (wind speed 17–21 kt or 32–39 km) or 4 (26%). This is typical for the summer in the study region (Pilot Chart, date unkn.). Aboard the *SJII*, most of the 394 h of observation effort was split fairly evenly across

TABLE 4.2. Sightings of cetaceans in the present seismic survey area in the SE Caribbean Sea and adjacent Atlantic Ocean during March and April 2000, and our estimates of densities from these sightings. Number of sightings is from Swartz and Burks (2000) and Swartz et al. (2001). Their survey effort in and near the seismic survey area was 1984 km with sea state ≤7. Most survey effort was in water depths <1000 m. Species in italics are listed as endangered.

		Density corrected for $f(0)$ and $g(0)$ (number/1000 km^2)		
Species	Number of Sightings (n)	Mean[a]	(CV)[b]	Density adjusted for partially identified animals[c] (number/1000 km^2)
Odontocetes				
Physeteridae				
Sperm whale	*0*	*0.00*	*(>1.00)*	*0.63*
Pygmy sperm whale	0	0.00	(>1.00)	0.02
Dwarf sperm whale	0	0.00	(>1.00)	0.02
Prorated "unidentified large whale"	2.53[c]	0.67	(0.79)	
Ziphidae				
Cuvier's beaked whale	0	0.00	(>1.00)	0.00
Gervais' beaked whale	0	0.00	(>1.00)	0.00
Blainville's beaked whale	0	0.00	(>1.00)	0.00
Delphinidae				
Rough-toothed dolphin	2	7.38	(0.83)	10.52
Tucuxi	0	0.00	(>1.00)	0.00
Bottlenose dolphin	4	21.20	(0.72)	26.95
Pantropical spotted dolphin	1	4.82	(0.94)	6.85
Atlantic spotted dolphin	2	12.57	(0.83)	16.61
Spinner dolphin	0	0.00	(>1.00)	0.78
Clymene dolphin	0	0.00	(>1.00)	0.78
Striped dolphin	0	0.00	(>1.00)	0.78
Long-beaked common dolphin	9	21.19	(0.58)	30.04
Fraser's dolphin	0	0.00	(>1.00)	0.49
Risso's dolphin	0	0.00	(>1.00)	0.49
Melon-headed whale	0	0.00	(>1.00)	0.49
Pygmy killer whale	0	0.00	(>1.00)	0.49
False killer whale	0	0.00	(>1.00)	0.49
Killer whale	0	0.00	(>1.00)	0.49
Bottlenose/spotted dolphin	1	3.18	(0.94)	
Unidentified dolphin	6	22.62	(0.65)	
Stenella sp.	1	3.80	(0.94)	
Short-finned pilot whale	0	0.00	(>1.00)	0.49
Mysticetes				
Humpback whale	*13*	*3.56*	*(0.52)*	*4.57*
Minke whale	0	0.00	(>1.00)	0.04
Bryde's whale	5	1.57	(0.68)	1.95
Sei whale	*0*	*0.00*	*(>1.00)*	*0.04*
Fin whale	*1*	*0.20*	*(0.94)*	*0.27*
Blue whale	*0*	*0.00*	*(>1.00)*	*0.04*
Unidentified Balaenoptera	3	0.71	(0.76)	
Prorated "unidentified large whales"	3.47[c]	0.88	(0.74)	
Sirenians				
West Indian manatee	0	0.00	(>1.00)	0.00

[a] Numbers are adjusted using $f(0)$ and $g(0)$ values from Koski et al. (1998). See text.

[b] CV (Coefficient of variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation $0.94 - 0.162\log_e n$ from Koski et al. (1998), but likely underestimates the true variability.

[c] "Unidentified" animals are assigned to each category based on the number of sightings of identified animals in each species group that is included in each "unidentified" category. Species that are expected to occur, but that were not sighted, were given a sighting of 0.5 during the assignment of unidentified animals to each species.

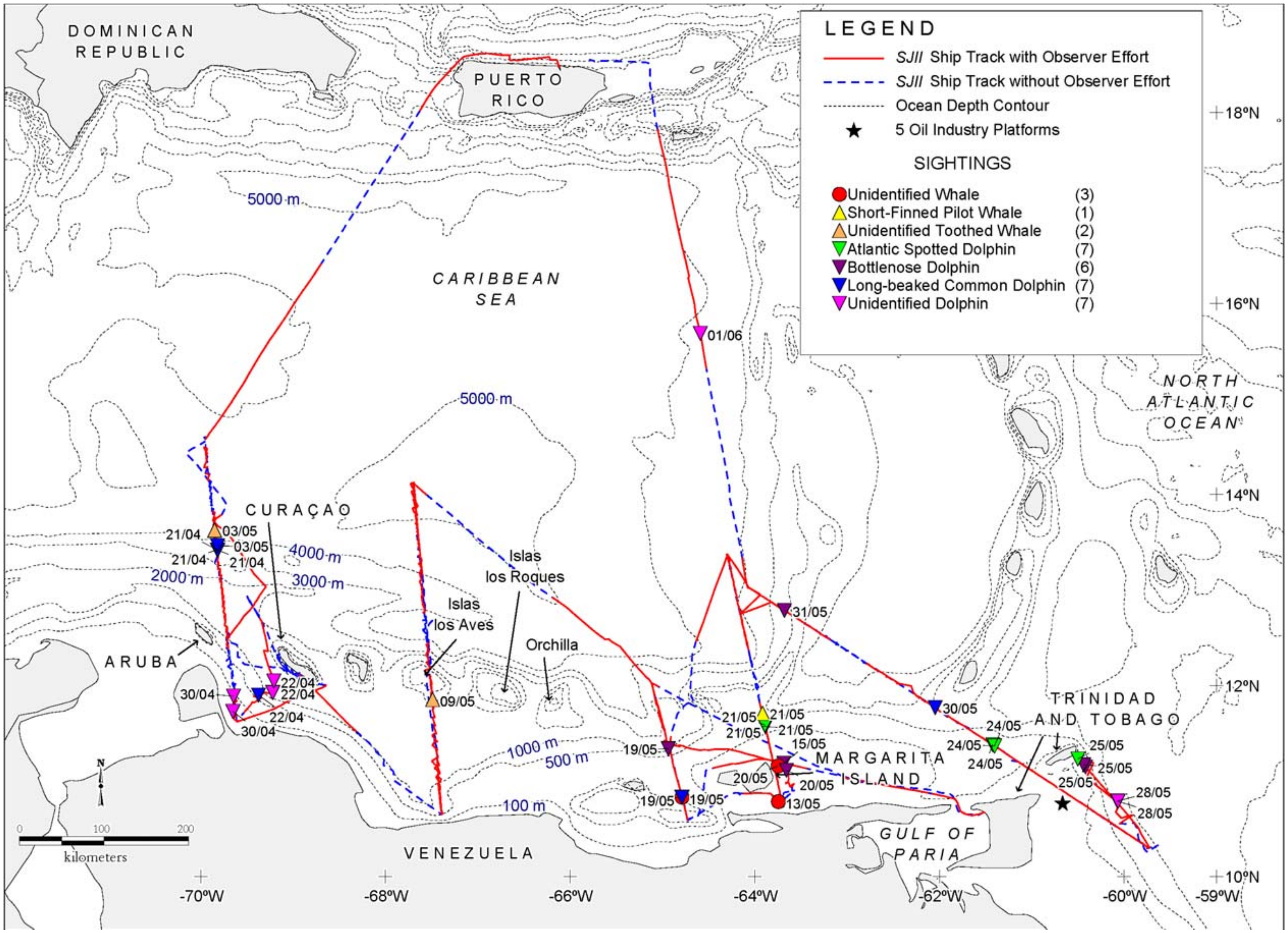

FIGURE 4.1. *SJII* ship track with and without observer effort, and also *SJII* visual sightings of cetaceans and associated dates. Ship track without observer effort occurred mainly at night.

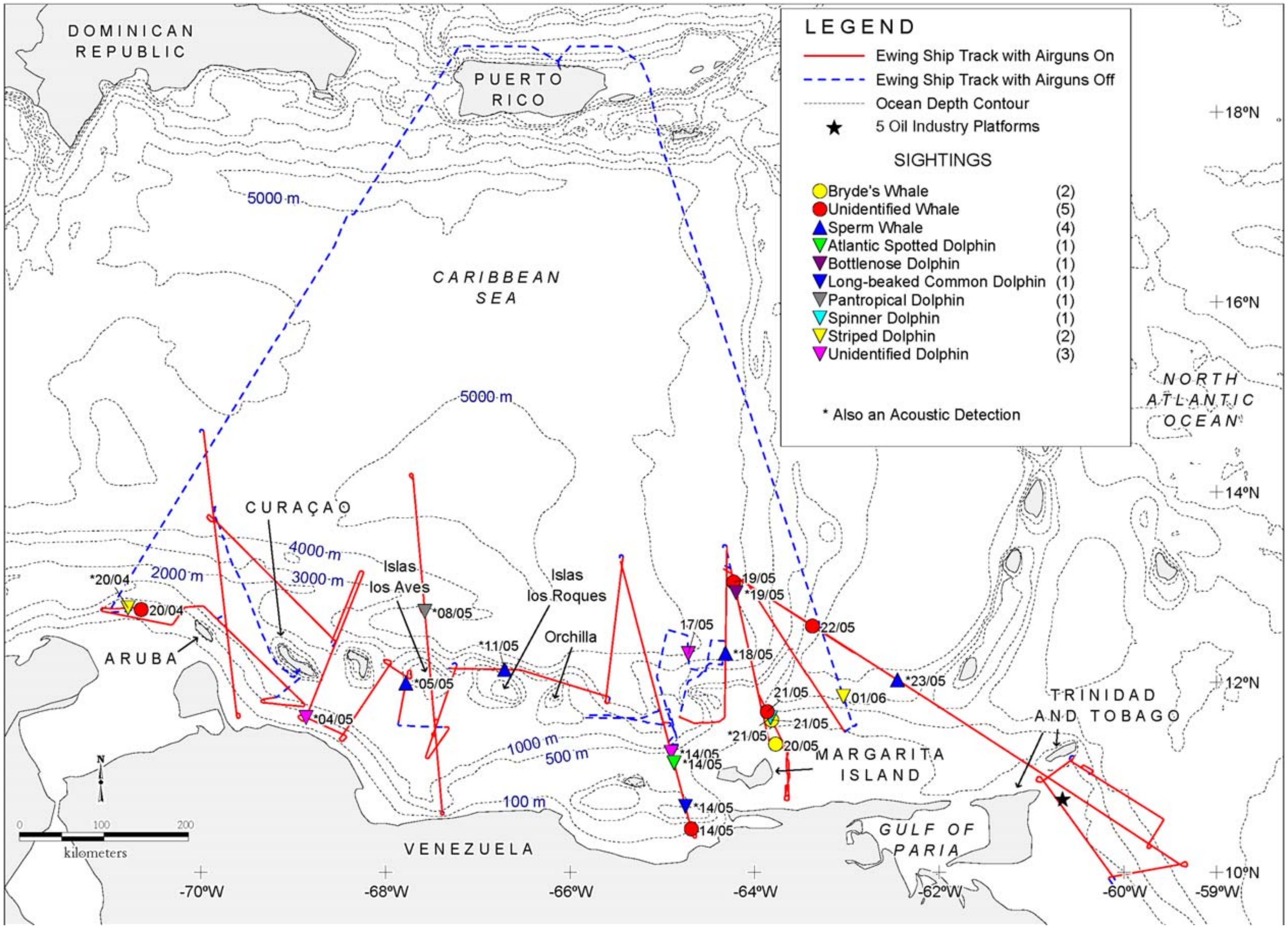

FIGURE 4.2. *Ewing* ship tracks with airguns on and off, with *Ewing* visual sightings of cetaceans and associated dates. Visual sightings matched with concurrent *Ewing* acoustic detections are also depicted.

Beaufort Forces 2 (27%), 3 (29%) and 4 (27%), with only 5% of effort occurring during Beaufort Force 5 (Appendix F.1). The differences in Beaufort Forces recorded during observations aboard the *Ewing* and *SJII* may be attributable to the fact that the *Ewing* remained in the open sea. In contrast, the *SJII* spent a considerable amount of time in the lee of various SE Caribbean Islands while transiting to island ports to conduct crew changes, repair equipment, or layover until the *Ewing* finished shooting OBS lines, etc.

Visual observation effort from the *Ewing* in hours (A) and kilometers (B), subdivided by airguns on vs. off and number of operating airguns, is depicted in Appendix F.2 and also Table ES.1 in the Executive Summary. In total, airguns were on (including ramp up) for 755 h and 6605 km, of which 425 h and 3662 km occurred while MMOs were on visual watch (Table ES.1). Airguns were off for a total of 329 h and 3183 km, of which 85 h or 1258 km occurred while the MMOs were on visual watch. As anticipated, the full 20-airgun array operated during the majority (343 h, 2936 km) of the period that airguns were on and *Ewing* MMOs were observing. During 52 h (452 km), 16–19 airguns were operating, typically during turns between seismic lines. A single airgun operated for 12 h (106 km) and airgun ramp ups occurred during 13 h (110 km) while MMOs were on watch. As described in Chapter 3, one 80 in^3 airgun was used during power downs when marine mammals and sea turtles were sighted within or approaching the safety radius around the 20 airguns, or while the *Ewing* approached a survey line or repaired equipment. There were not sustained periods with 2–7 airguns or 11-15 airguns operating while MMOs were on watch.

Visual observation effort from the *Ewing* and *SJII* in hours (A) and kilometers (B), subdivided by water depth, is depicted in Table 4.3. As anticipated in the project's IHA application (LGL Ltd. 2003b), the majority of the observation effort from the *Ewing* (325 of 510 h; 3286 of 4290 km) occurred while the *Ewing* was in deep (>1000 m) water, primarily with airguns on (260 h, 2229 km). The majority of the observation effort from the *SJII* (252 of 394 h; 3062 of 5087 km) also occurred in deep water, primarily while underway at speeds of ~9–10 kt during transits between OBS deployments and retrievals or during transit to other destinations (Table 4.3).

Visual Sightings of Marine Mammals and Other Vessels

Numbers of Marine Mammals Seen.—An estimated total of ~1294 individual marine mammals were seen in 47 groups during the SE Caribbean study period; all of these were cetaceans (Table 4.4; Fig. 4.1, 4.2; Appendix G). This total includes one floating, dead and decaying fin whale sighted by observers aboard the *SJII*. The death of this whale was determined to be unrelated to the *Ewing*'s airgun operations based on a review by NMFS and a panel of independent experts (see Appendix B). No other dead or injured animals potentially associated with the operations were sighted.

Nearly all groups (44 of 47) were seen within the study area—the remaining 3 groups were seen during the brief transits between San Juan and the study area: two from the *Ewing* and one from the *SJII* (Fig. 4.1, 4.2; Appendix G). The number of cetacean groups seen from the *Ewing* (n = 21) was slightly less than the number seen from the *SJII* (n = 26; see Tables ES.1 and 4.4). Also, nearly three times as many individual cetaceans were seen from the *SJII* (n = 927) as from the *Ewing* (n = 367). The higher number of individuals seen from the *SJII* was primarily attributable to one group of ~600 long-beaked common dolphins. Appendix G shows a detailed list of the sightings. Most groups (n = 18) and individuals (n = 301) sighted from the *Ewing* were observed while the airguns were operating (Table ES.1, Appendix G), consistent with the fact that most observation effort from the *Ewing* was with airguns operating. No cetaceans or sea turtles were seen during ramp ups or by bridge personnel (or MMOs) at night.

A total of 10 different species were documented visually from the *Ewing* or *SJII* during the survey. All of these species previously have been documented to occur in the SE Caribbean Sea (see Tables 4.1

TABLE 4.3. Marine mammal visual observation effort from the *Ewing* and *SJII* within and in transit to the SE Caribbean and adjacent North Atlantic study area, 18 April–3 June 2004, in ***(A)*** hours and ***(B)*** kilometers, subdivided by water depth and airgun activity. All except 6 h and 52 km of nighttime observations aboard the *Ewing* were during daytime; all this nighttime effort was with airguns operating. No effort was conducted with 2–7 airguns or 11–15 airguns operating for a sustained period. Ramp-up effort is included in the "Airguns On" category.

	Water Depth Range (m)			
Airgun Status	**<100**	**100-1000**	**>1000**	**Total**
***(A) Ewing* Visual Effort (h)**				
Airguns On	48	117	260	425
Ramping Up	*1*	*6*	*6*	*13*
Airguns Off	5	15	65	85
Total	**53**	**132**	**325**	**510**
***(B) Ewing* Visual Effort (km)**				
Airguns On	415	1011	2229	3654
Ramping Up	*11*	*51*	*49*	*110*
Airguns Off	26	182	1057	1266
Total	**441**	**1193**	**3286**	**4920**
***(A) SJII* Visual Effort (h)**				
Deploy/Retrieve OBSs	0	25	69	94
Underway in Study Area	0	107	150	257
Transit San Juan to/from Study Area	0	10	33	43
Total	**0**	**142**	**252**	**394**
***(B) SJII* Visual Effort (km)**				
Deploy/Retrieve OBSs	1	191	318	510
Underway in Study Area	4	1637	2122	3763
Transit San Juan to/from Study Area	0	193	620	813
Total	**5**	**2020**	**3062**	**5087**

[a] Ramping up involved firing by 1–19 airguns of the 20-airgun array.

and 4.4). Unidentified whales and unidentified dolphins (n = 7 of each) were the most commonly seen categories, followed by equal numbers of groups (n = 6 of each) of bottlenose, Atlantic spotted, and long-beaked common dolphin (Table 4.4). Four species of whales were observed: sperm whales (n = 4 groups), short-finned pilot whales (n = 3), Bryde's whales (n = 2), and the one dead fin whale (see Appendix B). Long-beaked common dolphins were the most numerous cetaceans, accounting for ~734 individuals in six groups, including one group of ~600 dolphins (Table 4.4). No sirenians or pinnipeds were seen. Sperm whales were detected only from the *Ewing* (9 groups: 4 visual/acoustic and 5 acoustic-only detections). Striped (n = 2), spinner (n = 1), and pantropical spotted dolphins (n = 1) were also observed only from the *Ewing*. Short-finned pilot whales (n = 3) and the one dead fin whale were observed only from the *SJII*.

TABLE 4.4. Number of visual and acoustic detections of groups of cetaceans from the *Ewing* and *SJII* during the SE Caribbean and adjacent North Atlantic seismic study, 18 April–3 June 2004. Data are presented separately for "seismic" and "non-seismic" (before and >6 h since airguns on) periods. All *SJII* sightings were considered "non-seismic", as described in Chapter 3, "Analyses". Numbers in parentheses are number of individuals. For acoustic encounters, group size was unknown unless there was a concurrent visually-matched sighting.

Species	*SJII* Visual Sightings (# indiv)	*Ewing* Visual-Only Sightings (# indiv)	*Ewing* Acoustic-Only Encounters	Matched *Ewing* Visual/ Acoustic Detections (# indiv)	Total Visual Sightings (# indiv)	Total Acoustic Encounters
Sperm whale	0	0	5	4 (12)	**4 (12)**	**9***
Bottlenose dolphin	5 (30)	0	0	1 (20)	**6 (50)**	**1***
Pantropical spotted dolphin	0	0	0	1 (30)	**1 (30)**	**1***
Atlantic spotted dolphin	5 (174)	0	0	1 (55)	**6 (229)**	**1**
Spinner dolphin	0	0	0	1 (80)	**1 (80)**	**1***
Striped dolphin	0	1 (60)	0	1 (7)	**2 (67)**	**1***
Long-beaked common dolphin	5 (684)	0	0	1 (50)	**6 (734)**	**1***
Unidentified dolphin	4 (18)	1 (4)	61	2(38)	**7 (60)**	**63***
Short-finned pilot whale	3 (17)	0	0	0	**3 (17)**	**0**
Bryde's whale	0	2 (3)	0	0	**2 (3)**	**0**
Fin whale	1 (1)**	0	0	0	**1 (1)****	**0**
Unidentified mysticete whale	0	1 (1)	0	0	**1 (1)**	**0**
Unidentified whale	3 (3)	4 (7)	0	0	**7 (10)**	**0**
Total	**26 (927)****	**9 (75)**	**66**	**12 (292)**	**47 (1294)****	**78**

*12 of the acoustic encounters are double-counted here under visual and acoustic because they were visual/acoustic matches.

** This was a dead, floating and decomposing carcass found by MMOs on the *SJII* on 15 May 2004. See text and Appendix B.

The density of cetacean visual sightings was closely associated with water depth. The highest densities occurred in intermediate water depths of 100–1000 m. Considerably lower cetacean densities were found in deep water (>1000 m), although the greatest effort occurred there (Table 4.3). Density trends relative to distribution and occurrence are discussed in detail later, incorporating correction factors for effort and sightability (see *Estimated Numbers of Marine Mammals Potentially Affected*).

Sightings with Airguns On.— Most (18 of 21) sightings from the *Ewing* were made while the airguns were on, primarily (16 of 18) while the full 20-airgun array was operating. Of the remaining two groups sighted with airguns on, one was sighted while 19 airguns were operating during a turn, and the other was seen during a ramp up (Appendix G). Nine of the 18 marine mammal groups sighted with guns on were first seen within the precautionary safety radius, and the airguns were powered-down. The airguns were powered down three times for one of these groups (a Bryde's whale; see Appendix G). Two of these groups (pantropical spotted and spinner dolphins) continued toward the 1-airgun safety radius, resulting in a full shut down of all the airguns (Appendix G).

Other Vessels and Platforms.—The IHA required that MMOs record the number and characteristics of vessels <5 km from marine mammal sightings (Appendix A). A total of four other vessels were seen in the SE Caribbean study area within ~5 km of marine mammal sightings. This included 3 cases involving fishing vessels near the *Ewing*, and 1 case involving a tanker near the *SJII*. However, over 30 vessels were seen throughout the study when no sightings were made, or at distances >5 km from sightings. These included primarily fishing vessels <30 m long, tankers, large cargo/freight vessels, recreational vessels (e.g., sailboats, yachts), and ferries. Also seen were a few other seismic vessels (e.g., the S/V *Western Patriot*), naval vessels, and a U.S. research vessel not involved in the work discussed in this report (the *Seward Johnson I*). Numbers of such vessels were not recorded systematically when no sightings were made or when the vessels were >5 km from sightings. The *SJII* was near the *Ewing* on several occasions for crew and supply transfers, but no marine mammal sightings were made during those periods. Several (2 to 3) seismic vessels and other seismic support vessels were sighted from the *Ewing* near (<10 km from) five oil industry platforms on 24 May and 26 May including one platform under construction. The *SJII* was in the same area on 25 and 28 May (Fig. 4.1). These platforms were located in the far southeastern portion of the study area ~30 km south of Tobago in the North Atlantic Ocean near ~60º40'W and ~10º45'N (Fig. 4.1-4.3).

Acoustic Survey Effort and Detection Results

A total of 846 h (7375 km) of acoustic monitoring was conducted from the *Ewing* (Fig. 4.3; Table ES.1). This effort began in the western part of the study area 4 h before the first airguns fired on 20 April, and ended in the eastern portion when the last airguns fired on 1 June (Table 2.2). Acoustic monitoring effort in hours (A) and kilometers (B), subdivided by day and night periods and number of operating airguns, is depicted in Appendix F.3. Acoustic effort was almost equally divided between daytime (437 h, 3787 km) and nighttime (406 h, 3562 km) periods. In total, airguns were on, including ramp up, for 800 h of the 846 h of acoustic monitoring effort (6800 of 7375 km) (Table ES.1, Appendix F.3).

There were 78 acoustic encounters with calling cetaceans during nearly 24 h/day of PAM from the *Ewing*. All 66 acoustic-only detections were unidentified dolphins (n = 61) or sperm whales (n = 5; Table 4.4). The other 12 acoustic encounters were matched with concurrent visual sightings of 7 different odontocete species; 9 of the 21 cetacean groups sighted from the *Ewing* were not detected acoustically. Most (99% of 78) acoustic encounters were heard during seismic periods. Acoustic encounters with delphinids were more common at night (11.5/1000 km) than during the day (7.4/1000 km), based on 69 acoustic encounters with delphinids: 61 acoustic-only unidentified dolphin encounters, 2 matched acoustic/visual encounters with unidentified dolphins, and 6 dolphin groups identified to species based on visual/acoustic matches. No mysticete vocalizations were detected during PAM, although 7 Bryde's, unidentified mysticete or other large whales were seen.

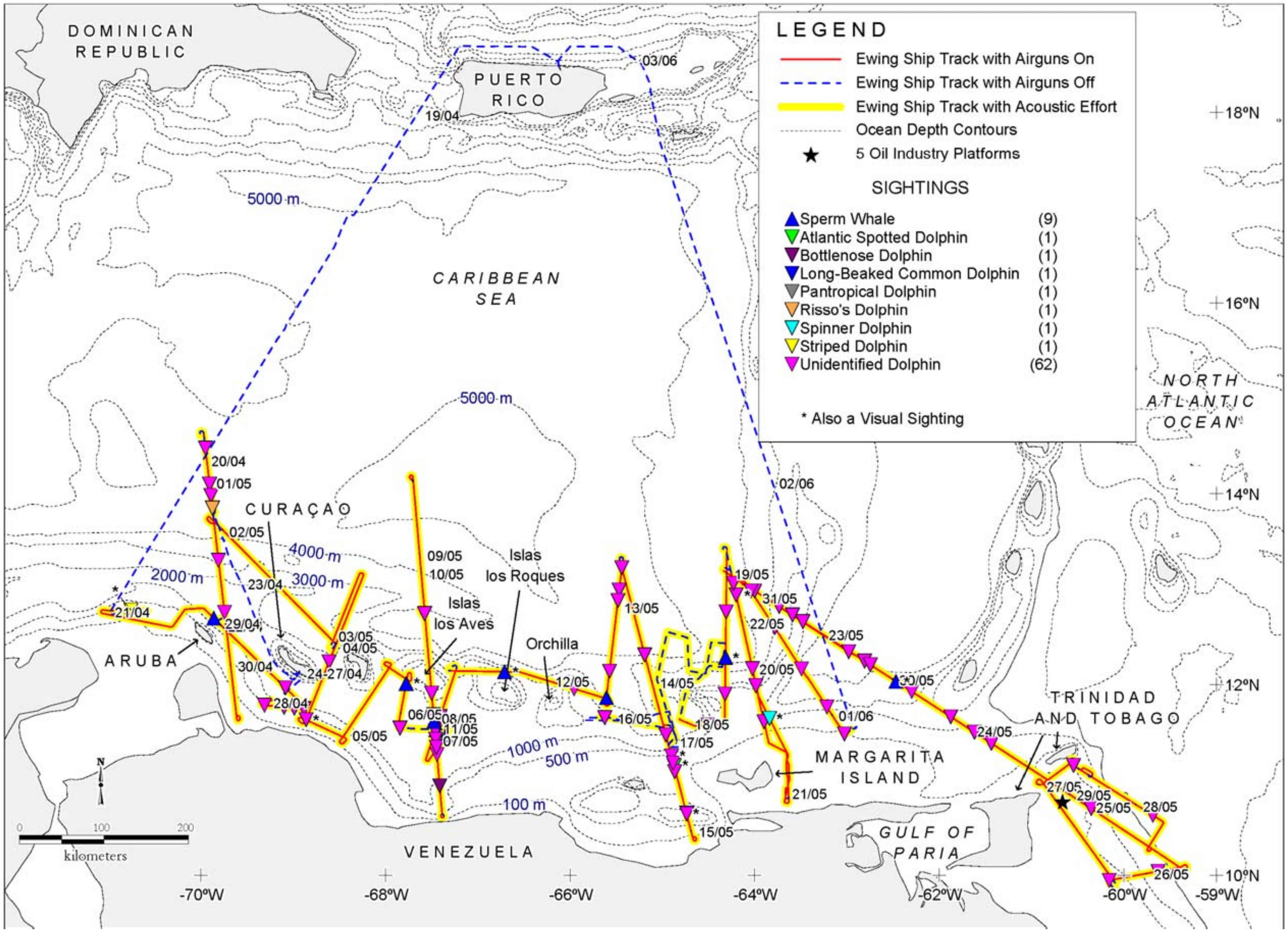

FIGURE 4.3. *Ewing* ship tracks with airguns on and off, acoustic monitoring effort, and acoustic detection locations and associated dates. Acoustic detections that have matched concurrent visual detections are also depicted.

Distribution of Marine Mammals

Locations of visual sightings and acoustic detections of cetaceans made from the *Ewing* and *SJII* in the study area are plotted in Figures 4.1–4.3. The distributions of both visual sightings and acoustic encounters are included in this section. As stated previously, prior to the 2004 SE Caribbean seismic study, few systematic surveys for cetaceans had been conducted in the project area, particularly in the western portion of the study area between ~65ºW and 71ºW. The limited data available prior to this cruise indicated that the occurrence of cetaceans probably increased from west to east in the Venezuelan Caribbean, with concentrations having been documented near Margarita Island. Past survey effort has been concentrated in the latter area (Swartz and Burks 2000; Swartz et al. 2001, 2003; A. Sayegh, CIC, pers. comm.). Increases in abundance from west to east have been attributed to observed increases in biological productivity from west to east in this region, which are associated with increased runoff from major rivers including the Orinoco to the east.

Visual and acoustic detections during the SE Caribbean study showed that cetaceans were distributed throughout much of the study area, with notable concentrations in some areas (Figs. 4.1–4.3). From west to east, detections of cetaceans were concentrated between Aruba and Venezuela,near Margarita Island, and near Trinidad and Tobago. This pattern was apparent from the distribution of cetaceans visually sighted from the *SJII* (Fig. 4.1) and to a lesser degree the *Ewing* (Fig. 4.2). All effort from the *SJII* was non-seismic. Concentrations of dolphins in the shallow (<100 m) waters just east of Paraguana Peninsula, at the western edge of the study area, were previously undocumented. Very few sightings or strandings had been reported there previously, and no previous surveys had been conducted there (A. Sayegh, CIC, pers. comm.). The acoustic detections, like the visual sightings, tended to be more common in the eastern part of the study area. However, acoustic detections were not as obviously concentrated in the three areas where visual sightings tended to occur (Fig. 4.3; *cf.* Fig. 4.1, 4.2). There was a concentration of acoustic detections in the deep trench between Islas los Aves and mainland Venezuela.

Some cetacean species were detected primarily in localized or specific areas. Sperm whales were seen and/or heard around islands and atolls of the Caribbean Archipelago, in waters near the 1000-m contour or deeper, including Islas los Roques, Orchilla, and Islas los Aves (Fig. 4.2, 4.3). Previous surveys in other parts of the Caribbean reported similar associations of sperm whales with the Caribbean Archipelago, mainly northeast of the project area (Watkins et al. 1985; Swartz and Burks 2000; Swartz et al. 2001, 2003). However, this pattern had not been reported previously for the 2004 project area. Bryde's whales and unidentified whales occurred primarily between ~63º and 65ºW around Margarita Island (Fig. 4.1, 4.2).

The distribution and abundance of cetaceans were related to water depth, and were also influenced by seismic status. Densities of cetaceans in water 100–1000 m deep were 5–8 times higher than those in water >1000 m (see *Estimated Numbers of Marine Mammals Potentially Affected*, later). Also, apparent densities during seismic periods were 35–55% of those during non-seismic periods. This indicates that the *Ewing*'s airgun sounds likely displaced some cetaceans locally, as expected from other studies of the effects of seismic sounds on cetaceans (see reviews in LGL Ltd. 2003a,b; Gordon et al. 2004).

Marine Mammal Behavior

Two types of data collected during visual observations with and without airgun operations provide information about behavioral responses to the seismic survey: estimated distances and types of behavior for animals sighted during seismic and non-seismic periods.

Sighting Distances

The closest observed point of approach (CPA) of cetaceans to the observation vessel tended to be closer during non-seismic periods, with a mean of 352 m, vs. seismic periods, with a mean of 1376 m (Table 4.5). This trend was true for both delphinids (non-seismic 172 m, seismic 991 m) and Bryde's / unidentified whales (1383 vs. 2190 m, respectively); see Table 4.5. The numbers of sightings of other species were too small to compare CPAs by species. These results are consistent with the possibility that some cetaceans avoided the seismic vessel, and did not come as close to the vessel during seismic periods. This trend is also in line with density results indicating that apparent cetacean densities were lower during seismic vs. non-seismic periods (see *Estimated Numbers of Marine Mammals Potentially Affected* below).

Categories of Behavior

Cetacean behavior is difficult to observe. Cetaceans are often at the surface only briefly, and there are difficulties in resighting individuals or groups, and in determining whether two sightings some minutes apart are repeat sightings of the same individual(s). Limited behavioral data were collected during this project, since cetaceans were generally seen at a distance from the vessel, and they were not tracked for long distances or times. The three parameters that were examined quantitatively to assess potential seismic effects on cetacean behavior were the first behavior and first movement observed (see Appendix C for variables and definitions), as well as the CPA recorded for each group sighting. The frequency of bow riding delphinids was also examined.

Behavioral observations were compared between seismic and non-seismic periods. Sample sizes were too small to permit valid comparisons for individual species. Thus, species were combined into delphinids (n = 33 groups) and large whales (Bryde's and unidentified whales, n = 9 groups); see Table 4.6. The four sperm whale sightings were kept separate because their behavior and vocalization types are very different from those of the other two groupings.

In general, the first observed behavior of cetacean groups was variable and sample sizes were small (Table 4.6). However, a few trends emerged for delphinids (Table 4.6). During non-seismic periods, surface active/mill (SAM) was the most frequently seen (60%) first behavior among delphinids (15 of 25 groups), followed by travel (9 or 36%). During seismic (n = 8), the most frequently observed first behavior was travel (50%) and SAM (38%).

During non-seismic periods, delphinids frequently (52%) moved toward the *SJII* (13 of 25 groups; Table 4.6). The remaining 12 delphinid groups initially swam parallel (n = 8) or swam away from (n = 4) the *SJII*. During seismic, the sample size from the *Ewing* was small (n = 6 groups with known first movements; Table 4.6).

Three of 25 delphinid groups (or 12%) bow-rode the *SJII*. Neither of the two delphinid groups observed from the *Ewing* during non-seismic periods bow-rode. During seismic periods, no delphinid groups (0 of 8) bow rode the *Ewing*.

It is uncertain why delphinids apparently moved toward the *SJII*, and sometimes bow-rode that vessel, more frequently than the *Ewing*. When the *Ewing's* airguns were active, the airgun sounds may have deterred them. However, the *SJII* typically traveled twice as fast as the *Ewing* (9–10 vs. 4–5 kt). Species that habitually bow-ride may have been attracted by the faster-traveling ship. Nearly all delphinid sightings from the *Ewing* (8 of 10 groups) were made during seismic periods while the *Ewing* traveled at 4–5 kt. The remaining two delphinid groups were observed during non-seismic periods when the *Ewing* was transiting at 10–11 kt. In contrast, aboard the *SJII*, all observations were considered non-seismic, and all but 3 of 22 delphinid sightings were made while the *SJII* was in fast transit (as opposed to

TABLE 4.5. Closest observed points of approach (CPA) of cetacean groups visually observed during non-seismic and seismic periods in the SE Caribbean and adjacent North Atlantic seismic study, 18 April–3 June 2004. "Seismic" includes only *Ewing* visual sightings; "non-seismic" includes three *Ewing* sightings before or >6 h after airguns were on, plus all *SJII* sightings, as described in Chapter 3, "Analyses".

	Non-seismic				**Seismic**			
Species	**Mean CPA (m)**	**SD**	***n***	**Range (m)**	**Mean CPA (m)**	**SD**	***n***	**Range (m)**
Sperm whale	-	-	0	-	1460	729.5	4	654 – 2410
Delphinids[1]	172	239.7	24	05 - 654	991	1103.9	8	15 – 2729
Bryde's whale/ Unid. whale	1383	1292.4	4	533 - 3300	2190	1433.2	5	900 – 4633
Total	352	658.4	28	0.5 - 3300	1376	1167.1	13	15 – 4633

[1]**Delphinids** include dolphins and 3 short-finned pilot whale groups sighted from the *SJII* during the non-seismic period.

TABLE 4.6. Comparison of first observed movement and behavior of cetacean groups visually observed during non-seismic and seismic periods in the SE Caribbean and adjacent North Atlantic seismic study area, 18 April–3 June 2004. "Seismic" includes only *Ewing* visual sightings; "non-seismic" includes three *Ewing* sightings before or >6 h after airguns were on, plus all *SJII* sightings, as described in Chapter 3, "Analyses". See Appendix C for description of behavior categories.

	First Observed Behavior						**First Observed Movement**					
Species	**Blow**	**Travel**	**Surf. Active/Mill (SAM)**	**Stat.**	**Dive**	**Total**	**Away**	**Parallel**	**To**	**None**	**Unk**	**Total**
Sperm whale												
Non-seismic	NA	NA	NA	NA	NA	**0**	NA	NA	NA	NA	NA	**0**
Seismic	2	1	0	1	0	**4**	1	1	0	1	1	**4**
Delphinids												
Non-seismic[1]	0	9	15	0	1	**25**	4	8	13	0	0	**25**
Seismic	0	4	3	1	0	**8**	1	2	3	0	2	**8**
Bryde's whale/ Unid. whale												
Non-seismic	3	1	0	0		**4**	1	2	0	0	1	**4**
Seismic	3	2	0	0		**5**	2	1	0	0	2	**5**
Total												
Non-seismic	**3**	**10**	**15**	**0**	**1**	**29**	**5**	**8**	**13**	**1**	**1**	**29**
Seismic	**5**	**7**	**3**	**2**	**0**	**17**	**4**	**4**	**3**	**1**	**5**	**17**
Total	**8**	**17**	**18**	**2**	**1**	**46**	**9**	**12**	**16**	**2**	**6**	**46**

[1]**Delphinids** include dolphins and 3 short-finned pilot whale groups sighted from the *SJII* during the non-seismic period.

slowly deploying or retrieving OBSs, usually at <3 kt). Small sample sizes prevent an analysis of the relative contributions of ship speed and non-seismic vs. seismic status on delphinid movement patterns and propensity to bow-ride.

Acoustic Monitoring Results

This section discusses the results of the SE Caribbean passive acoustic monitoring (PAM) program. A review of the utility and limitations of the SEAMAP system for monitoring cetaceans during seismic operations from the *Ewing* is also included. As summarized in Chapter 3, the SE Caribbean seismic project was the first time that an IHA issued to L-DEO required acoustic monitoring for the purpose of aiding visual observers in detecting cetaceans. Prior to this cruise, there was little information about the utility and practicality of SEAMAP operations aboard the *Ewing* during routine seismic operations. In practice, there were multiple "start-up" problems in implementing effective PAM operations. These problems included difficulties with SEAMAP hardware and software, and with the compatibility of the SEAMAP system with ongoing *Ewing* operational systems (e.g., GPS, navigation software, electronic interference, etc.). Nonetheless, valuable results were obtained with the SEAMAP system. With the resolution of some problems during this Caribbean cruise, it is expected that SEAMAP operations will be more routine in the future.

A SEAMAP system had been deployed from the *Ewing* during a short and specialized project in the northern Gulf of Mexico during 2003 (LGL Ltd. 2003c), but that was not a typical seismic survey. The questions that remained to be answered included

- the logistics of simultaneously towing the airgun array, 6-km-long streamer, and SEAMAP hydrophone array,
- scheduling issues associated with maintaining both round-the-clock acoustic monitoring and near-continuous daytime visual monitoring with a limited number of MMOs,
- the effect of strong airgun sounds, combined with routine ship sounds and flow noise on the ability to detect cetacean calls, and
- whether cetaceans could be localized via SEAMAP, and if so, whether localization would be limited to bearings or whether distances could also be determined at some times.

The IHA required that acoustic monitoring be conducted during the day as possible, and at night when marine mammals had been heard calling during the previous day (see Appendix A). However, MMOs aboard the *Ewing* maintained a nearly 24-h acoustic watch schedule while at sea in the study area, regardless of whether marine mammals had been detected during daylight (see Chapter 3). This ensured that, in the present cruise, visual and/or acoustic monitoring from the *Ewing* occurred during nearly all periods, day and night, that the airguns operated from the *Ewing*.

Acoustic Encounters

The SEAMAP hydrophone array used aboard the *Ewing* had not been calibrated prior to the SE Caribbean seismic study. It was not known how far away cetaceans would be detected with this system, as installed on the *Ewing*. The SEAMAP manual estimated that the maximum distance at which calling dolphins could be heard would be ~2 km, and that sperm whales could be heard up to ~5 km away (SEAMAP 2003). Background noise during the study typically included sea wave noise associated with the predominant Beaufort Wind Forces of 4–5, snapping shrimp, and occasional static interference from undetermined sources. The frequency range of dolphin calls overlaps little with the dominant low-frequency components of the airguns (LGL Ltd. 2003a,b). The SEAMAP system was limited to frequencies of 8 Hz to ~22 kHz. Dolphin communication sounds are predominantly from ~0.1 to 25 kHz, mainly within the frequency band monitored via SEAMAP. (Their echolocation sounds would be mainly at higher frequencies.) Sperm whales produce sounds at frequencies of 0.1 to 30 kHz, with dominant frequencies at 2–4 and 10–16 kHz (see review by Richardson et al. 1995).

For analysis purposes, an acoustic encounter was defined as any cetacean calls of the same species or species group (as identifiable) separated by <1 h. This definition followed previously established acoustic data collection protocol (Manghi et al. 1999). A total of 78 acoustic encounters were recorded from the *Ewing*, 12 of which were matched with visual sightings from the *Ewing* (Table 4.4, Appendix G). Mean encounter length was 0.6 h (SD = 0.80, range: 0.001–5.35 h) or 5.2 km (SD = 7.18 km, range: 0.006–48.49 km). The longest encounters occurred at night and consisted of apparent multiple subgroups of unidentified dolphins producing frequency-modulated whistles, usually in intermittent bursts. These encounters typically started faintly, increased in signal strength, and then faded as they appeared to "pass by" the hydrophone array located ~250 m aft of the vessel. The hydrophones were ~14–20 m deep, depending on the current, water depth, tow speed, etc.

The only cetacean calls that could be identified positively to species without visual confirmation were those of the sperm whale. There were 9 sperm whale acoustic encounters, 4 of which were coincident with visual sightings (Table 4.4; Appendix G). The vast majority (81%) of the 78 acoustic encounters were unidentified dolphins (n = 63, consisting of 61 acoustic-only and 2 matched acoustic/visual encounters). Given the interspecies similarities in frequency ranges, whistle types, etc., it was not possible to differentiate dolphin calls by species with confidence, particularly while in the field (C. Fossati, CIBRA, pers. comm.). However, based on matching acoustic encounters with simultaneous visual sightings from the *Ewing*, there was one acoustic encounter with each of the following species of dolphins: bottlenose, pantropical spotted, Atlantic spotted, striped, and long-beaked common dolphin (Table 4.4, Appendix G).

Acoustic Encounter Rates

Encounter rates were calculated based on the number of acoustic encounters per hour and per 1000 km of acoustic monitoring effort. Given a total of 78 acoustic encounters from the *Ewing*, the overall acoustic encounter rate was 0.10 encounters per hour or 10.6 encounters per 1000 km (Table 4.7). The total number of acoustic encounters and encounter rates was higher at night (n = 43, 12.1/1000 km) than by day (n = 35, 9.2/1000 km), with nearly equal effort by night and day (Table 4.7). In particular, delphinids were heard more frequently at night (n = 41, 11.5/1000 km) as during the day (n = 28, 7.4/1000 km; Table 4.7). The opposite pattern was seen with sperm whales: 7 of 9 acoustic encounters occurred during the day (Table 4.7).

Acoustic encounter rates were compared between seismic and non-seismic periods, with the latter being times before seismic operations or when no airguns had been on for at least 6 h. These comparisons were limited to delphinids and sperm whales; no baleen whales were heard vocalizing during the study. Depending whether one considers hours or kilometers of effort, there was 6 to 11 times more acoustic monitoring effort during seismic periods (800 h, 6800 km) than during non-seismic periods (43 h, 549 km). Only one acoustic encounter occurred during non-seismic periods, as compared with 77 encounters during seismic periods (Table 4.8). As a result, acoustic detection rates during non-seismic periods were very low (≤0.02/h and ≤1.8/1000 km) for all species groupings compared to those during seismic (Table 4.8). The overall acoustic encounter rate was about 8 times higher for "all delphinids" than for sperm whales. There were nine acoustic encounters with sperm whales as compared to 69 acoustic encounters with delphinids (Table 4.8).

TABLE 4.7. Number and rates of acoustic encounters with cetaceans during night and day periods with acoustic monitoring effort aboard the *Ewing* in the SE Caribbean and adjacent North Atlantic seismic[1] study area, 20 April–1 June 2004.

	Day			Night			Total		
Species	No. of Encounters	No./h (Effort 437 h)	No./1000 km (Efffort 3787 km)	No. of Encounters	No./h (Effort 406 h)	No./1000 km (Effort 3562 km)	No. of Encounters	No./h (Effort 843 h)	No./1000 km (Effort 7349 km)
Sperm whale	7	0.02	1.9	2	0.01	0.6	9	0.01	1.2
Unident. Dolphin	20	0.05	5.3	39	0.10	10.9	59	0.07	8.0
Other delphinids	8	0.02	2.1	2	0.01	0.6	10	0.01	1.4
All delphinids	28	0.06	7.4	41	0.10	11.5	69	0.08	9.4
Total	35	0.08	9.2	43	0.11	12.1	78	0.1	10.6

[1] Excludes 3 h of undetermined effort.

TABLE 4.8. Number and rates of acoustic encounters with cetaceans during non-seismic periods (before and >6 h after seismic) and seismic periods with acoustic monitoring effort aboard the *Ewing* in the SE Caribbean and adjacent North Atlantic seismic study area, 20 April–1 June 2004.

	Non-Seismic			Seismic			Total		
Species	No. of Encounters	No./h (Effort 43 h)	No./1000 km (Efffort 549 km)	No. of Encounters	No./h (Effort 803 h)	No./1000 km (Effort 6800 km)	No. of Encounters	No./h (Effort 846 h)	No./1000 km (Effort 7349 km)
Sperm whale	0	0	0	9	0.01	1.3	9	0.01	1.2
Unident. dolphin	1	0.02	1.8	61	0.08	8.9	62	0.07	8.4
Other delphinids	0	0	0	7	0.01	1.0	7	0.01	0.9
All delphinids	1	0.02	1.8	68	0.08	9.9	69	0.08	9.4
Total	1	0.02	1.8	77	0.10	11.3	78	0.09	10.6

Utility of SEAMAP for Mitigation and Monitoring

Results of the SE Caribbean passive acoustic monitoring program indicate that there are benefits as well as limitations to using PAM aboard the *Ewing* for mitigation and monitoring purposes during L-DEO seismic projects. The primary benefits are as follows: ***(A)*** PAM can be conducted at night and during poor daytime observation conditions when visual observations are impossible or compromised (e.g., fog, rain, high winds, etc.). ***(B)*** PAM can often detect vocalizing cetaceans while they are below the surface, and invisible to visual observers. This information can be used to alert visual observers, providing information on presence, species or species group, and occasionally location (e.g., possible bearings and distances) before the animal(s) are seen. ***(C)*** MMOs can independently monitor airgun activity and other underwater noise sources, including whether airguns and bathymetric sonars are on or off, presence of large vessels nearby, and presence of other operating sources of seismic noise.

Primary limitations of PAM as used aboard the *Ewing* during this cruise included the following: ***(1)*** Non-vocalizing marine mammals could not be detected. ***(2)*** The bearing and distance to calling cetaceans could not be determined reliably during seismic operations for a number of reasons. (See Chapter 3 for a discussion of the limitations of a towed hydrophone array for locating calling marine mammals, specifically during a straight-line seismic survey.) ***(3)*** The SEAMAP system had not been calibrated, thus limiting use of received levels as an indicator of distances to calling cetaceans. ***(4)*** PAM cannot be used in shallow water, because of possible damage to the towed array of hydrophones. In addition, towing the array at a shallow depth limits the distance to which calls can be received. In summary, SEAMAP can be used to detect the presence of calling marine mammals in the general area, but (as implemented in this cruise) could not be used to determine whether those marine mammals were approaching or within NMFS-designated safety radii.

PAM did aid the visual observers in detecting cetaceans. Of the 12 matched acoustic/visual detections from the *Ewing,* six were first detected acoustically. In those cases, information about the acoustic detection was communicated to visual observers before the animals were seen (Appendix G). The duration of encounters was longer for acoustic detections (mean = 46 min, SD = 87.5 min, range 2–321 min, n = 12) than for visual sightings (mean = 31 min, SD = 34.7 min, range 1–130 min, n = 12). Neither visual nor acoustic contact was continuous over the entire encounter period. In addition, marine mammal calls often continued to be heard after MMOs could no longer see the animals. PAM provides a longer period of time to detect a marine mammal, and allows detection of calling mammals while they are below the surface and invisible. The longer average durations of acoustic encounters are to be expected given that many cetaceans spend relatively little time at the water surface compared to underwater.

Results indicate that PAM techniques detected marine mammal groups more frequently than did visual techniques during daytime-only periods (Table 4.9) and especially at night, when visual methods were essentially ineffective. As a result, detection rates during day and night combined were higher with PAM than by visual means (Table 4.4). PAM, unlike visual observations, can be conducted successfully during both day and night.

During daylight hours with simultaneous visual and acoustic effort, there were over twice as many acoustic detections (n = 38) as visual detections (n = 18; Table 4.9). The six visual-only detections that did not have coincident acoustic detections involved large whales, including 2 Bryde's whales, 3 unidentified whales, and 1 unidentified mysticete whale, possibly a Bryde's whale (Table 4.9). All 38 acoustic encounters during daylight hours consisted of dolphins (31 encounters) or sperm whales (7 encounters). Only four of seven sperm whale acoustic encounters during the day were visually detected. The results suggest that large whales (with the exception of sperm whales) were unlikely to be detected by PAM under the conditions of this seismic study, even when they were sighted visually (Table 4.9). However, PAM was considerably more efficient than visual observers at detecting dolphins during the study conditions.

In summary, both visual and PAM monitoring techniques contributed to the observation effort, and complemented one another. Combined use of the two methods increased the likelihood of detecting marine mammals during the *Ewing* seismic operations in the SE Caribbean seismic study. During daytime, use of both techniques simultaneously increased the number of detections relative to that with either technique individually. At night, only PAM was effective in detecting cetaceans. Simultaneous use of PAM and visual methods during daytime may have increased the number of cetaceans detected by visual observers.

As applied during this cruise, PAM was of little direct use in implementing mitigation measures, as distances to the detected cetaceans typically could not be determined from acoustic data alone. Furthermore, set-up complications and ongoing challenges associated with interfacing SEAMAP with existing shipboard systems limited the reliability of SEAMAP during the SE Caribbean cruise. The need to learn the new system, and to operate it and the geophysical equipment simultaneously, required considerable time and effort, and two additional MMOs with acoustic experience. Nonetheless, L-DEO plans to continue to utilize PAM where appropriate, particularly during operations with large airgun arrays in water depths >40 m—the minimum depth at which the system can be operated safely.

TABLE 4.9. Number of visual sightings and acoustic detections of cetacean groups during daylight periods with simultaneous visual and PAM monitoring from the *Ewing* in the SE Caribbean and adjacent Atlantic Ocean seismic study area, 20 April–1 June 2004.

Species	***Ewing* Visual-Only Sightings**	***Ewing* Acoustic-Only Encounters**	**Coincident "Matched" *Ewing* Visual/Acoustic Detections**	**Total Visual Sightings**	**Total Acoustic Detections**
Sperm whale	0	3	4	4	7
Bottlenose dolphin	0	0	1	1	1
Pantropical spotted dolphin	0	0	1	1	1
Atlantic spotted dolphin	0	0	1	1	1
Spinner dolphin	0	0	1	1	1
Striped dolphin	0	0	1	1	1
Long-beaked common dolphin	0	0	1	1	1
Unidentified dolphin	0	23	2	2	25
Bryde's whale	2	0	0	2	0
Unidentified mysticete	1	0	0	1	0
Unidentified whale	3	0	0	3	0
Total	**6**	**26**	**12**	**18**	**38**

Mitigation Measures Implemented

Eleven power downs had to be implemented due to cetaceans entering the safety radii (Table 4.10; also Appendix G). Two of these power downs resulted in complete shut downs, and three of the power downs occurred because the same animal entered the safety radius three times. All power downs occurred because the animal(s) were sighted within the safety radius; no power downs occurred before the animal(s) entered the safety radius. Some of these mammals were probably exposed to received levels ≥180 dB re 1 µPa (rms) before the airguns were shut down. (The numbers involved are estimated in the next section.)

Ramp ups were required during the day and night, whenever the airguns were started up after a prolonged period of inactivity, or from a power down, or to increase the number of guns firing. Three ramp ups occurred at night. None of these ramp ups were implemented following power downs. All ramp ups occurred just before nightfall in water deeper than 100 m. The array was ramped up from one airgun to 20 firing airguns.

On two occasions in late April, nighttime ramp-up procedures specified in the IHA, dated 16 April, were followed instead of the more restrictive procedures of NMFS (2004), applied after 14 May. This involved two nighttime ramp ups. The IHA *per se* did not prohibit a nighttime ramp up from 1 airgun if cetacean calls were heard during the preceding day or earlier that night. In addition, neither the IHA nor the *Federal Register* notice specified that PAM was to be used for implementing power downs or shut

TABLE 4.10. Cetacean sightings and mitigation measures implemented during the SE Caribbean seismic cruise, mid-April to early June 2004.

Species	Group Size	Date in 2004	Initial sighting distance	CPA[1] (m)	Move-ment[2]	Water Depth (m)	Visual (V) and/or Acoustic (A) Detection[3]	Mitigation Measure[4]	Likelihood of Exposure[5]
Pantropical spotted dolphin	30	8-May	50	20	SP	4462	A/V*	PD&SD	Possible
Sperm whale	6	11-May	1519	1258	NO	709	A*/V	PD	Unlikely
Atlantic spotted dolphin	55	14-May	2410	176	UN	150	A/V*	PD	Unlikely
Long-beaked common dolphin	50	14-May	4000	1017	SP	951	A/V*	PD	Unlikely
Bottlenose dolphin (prob. id.)	20	19-May	15	15	ST	3119	A/V*	PD	Possible
Unid. whale	2	19-May	1000	900	SA	3190	V	PD	Unlikely
Bryde's whale[6]	1	20-May	3200	1958	SA	35	V	PD	Possible
Spinner dolphin	80	21-May	2729	20	ST	360	A/V*	PD&SD	Possible
Sperm whale	1	23-May	654	654	SA	1800	A*/V	PD	Unlikely

[1] CPA is the closest point of approach to the vessel; not necessarily the distance at which the individual or group was initially seen.
[2] Initial movement of group relative to the vessel. UN=unknown, NO=no movement, SA=swimming away, SP=swimming parallel, ST=swimming toward.
[3] Initial detection denoted by *.
[4] This is the mitigation measure that was undertaken if necessary. PD=power-down, SD=shut-down,
[5] The likelihood of exposure refers to whether or not the sighting was likely to have been exposed to received levelsl >180 dB
[6] This whale entered the safety radius three times, so three power downs were implemented.

downs of the airguns. Use of PAM in that way would have been very problematic if it had been required, given the uncertainty of distance estimates obtained with this method. On the two occasions in late April, PAM indicated that dolphins were in the area and calling, but they were apparently far away, given that their calls were faint:

- At the commencement of the survey, on 20 April, a single airgun was started before nightfall in Beaufort Force 5. This airgun was on for ~4 h, after which time a nighttime ramp up commenced on 21 April, just after midnight GMT and about 1 h after sunset. Dolphins were heard calling progressively more faintly before and during nighttime ramp up from one 80 in^3 airgun to 20 airguns. Beaufort Force at the time of the ramp up was still 5. Water depth was intermediate (about 600 m) at the time of the ramp up, so the safety radius for 20 airguns was 1350 m (Table 3.1). The dolphin group had been seen earlier by visual MMOs at a distance of ~2160 m while it was still light on 20 April GMT, and was identified as "probable striped dolphins". The group was last seen at ~3000 m near dusk, moving away from the vessel, 120 min before ramp up began. Based on PAM, the dolphins were judged to be well outside the safety radius for intermediate water depths before and during the ramp up. The SEAMAP bearing and distance-estimating features were not working at the time of this sighting. However, the MMO bioacoustic specialist and other MMOs on the *Ewing* delayed and prolonged ramp up of the airguns until the dolphin calls were faint (far away). The entire ramp up took ~100 min (longer than a typical ramp up of ~25 min). The dolphins were last detected acoustically (faint signals only) when 16 airguns were on. No cetaceans were sighted by the visual observers using NVDs during the nighttime ramp up.
- On 27 April, a ramp up was initiated even though dolphins had been detected acoustically prior to the ramp up. After a shut down of ~5 days for mechanical repairs, one airgun started firing before dark on 27 April, at ~23:00 GMT. The ramp up was initiated in darkness on 28 April at 07:50 a.m. GMT, with water depth ~900 m. Calls of unidentified dolphins were periodically

detected on 28 April from 01:22 GMT to 09:00 GMT and were heard throughout the ramp up procedure. It was estimated that the group was located outside of the 1350 m safety radius (because calls were faint), and ramp up continued. No cetaceans were sighted by the visual observers using NVDs during the nighttime ramp up.

The third ramp up at night occurred in deep (~1400 m) water after the array had been shut down because of the floating, dead fin whale. The array was shut down for ~56 h, starting on 15 May. On 17 May, one airgun was started before nightfall, and the airgun array was then (during the night) ramped up to full capacity. Although cetacean calls were detected at midnight GMT on 16 May, it was deemed that any cetaceans detected on 16 May, and not heard thereafter, would have very likely moved out of the study area before airgun operations commenced on 17 May.

On one occasion, daytime ramp-up procedures specified in the IHA were followed instead of the more restrictive procedures applied after 14 May. Starting on 14 May, ramp up from a shut down could not begin during the day unless the entire 180-dB safety radius was visible (i.e., no ramp up could begin in heavy fog or high sea states of Beaufort Force 5 or higher). Fog was not an issue in the SE Caribbean survey area. However, high sea states often occurred.

- On 8 May, a shut down occurred for pantropical spotted dolphins. The airguns were shut down for 20 min, so a ramp up was required to return to full airgun capacity. However, the Beaufort Force was 5, so according to the *Federal Register*, a ramp up would not have been possible. However, on the date in question, the *Ewing* was following the mitigation measure outlined in the IHA. Had the ramp up not occurred, it may not have been possible to ramp up the array for the rest of 8 May, or even until 11 May, since sea states remained at Beaufort Force 5 or greater until then, at least during daytime.

Estimated Number of Marine Mammals Potentially Affected

It is difficult to obtain meaningful estimates of "take by harassment" for several reasons: ***(1)*** The relationship between numbers of marine mammals that are observed and the number actually present is uncertain. ***(2)*** The most appropriate criteria for "take by harassment" are uncertain and presumably variable among species and situations. ***(3)*** The distance to which a received sound level exceeds a specific criterion such as 190 dB, 180 dB, 170 dB, or 160 dB re 1 µPa (rms) is variable. It depends on water depth, airgun depth, and aspect for directional sources (Greene 1997; Greene et. al. 1998; Burgess and Greene 1999; Caldwell and Dragoset 2000; Tolstoy et al. 2004a,b). ***(4)*** The sounds received by marine mammals vary depending on their depth in the water, and will be considerably reduced for animals at the surface (Greene and Richardson 1988; Tolstoy et al. 2004a,b).

As noted earlier (Chapter 3), any large cetacean or beaked whale that might have been exposed to airgun pulses with received sound levels ≥160 dB re 1 µPa (rms) was assumed to have been potentially disturbed. Such disturbance was authorized by the IHA issued to L-DEO. The 160 dB criterion was developed by NMFS from studies of baleen whale reactions to seismic pulses (Richardson et al. 1995). That criterion is not likely to be appropriate for delphinids given what is known about the relative insensitivity of their hearing to low frequency sounds, and given the available data on their behavioral reactions to airgun sounds (LGL Ltd. 2003a,b; Gordon et al. 2004). Probable exposure to received levels ≥170 dB was used as an alternative criterion for estimating potential disturbance of delphinids. The sound levels received from the 20-airgun array were predicted to be ≥160 dB re 1 µPa (rms) out to estimated distances of 9 km, 10 km and 12 m in respective water depths >1000 m, 100–1000 m, and <100 m. The corresponding distances where sound levels were predicted to be ≥170 dB re 1 µPa were

2.6, 3.9 and 7 km, respectively. These predictions were based on modeling and results of acoustic measurements made by L-DEO in deep and shallow waters of the Gulf of Mexico during late May to early June 2003 (Table 3.1; Tolstoy et al. 2004a,b). For deep water, the distances quoted above are believed to be precautionary (i.e., larger than actual 160 and 170 dB distances).

Under NMFS procedures and the present IHA, mitigation measures are required in order to avoid or minimize the exposure of cetaceans to received levels of impulse sounds ≥180 dB re 1 μPa (rms). Levels were anticipated to be (at times) ≥180 dB at distances up to 0.9, 1.35 and 3.5 km in deep, intermediate, and shallow water, respectively (Table 3.1). Safety radii for pinnipeds were based on the estimated 190 dB distances (Table 3.1). However, no pinnipeds were expected to occur in the study area, and in fact none were seen during this project. We assume that no pinnipeds were disturbed or otherwise affected.

This section applies several methods to estimate the number of marine mammals exposed to airgun sound levels strong enough that they might have caused disturbance or other effects. These procedures include ***(A)*** minimum estimates based on direct observations, ***(B)*** estimates based on cetacean densities obtained in the study area via visual observations from the *Ewing* and *SJII* during periods unaffected by seismic surveys, and ***(C)*** estimates based on densities obtained by observers aboard the *Ewing* while it was conducting seismic surveys in the study area. It is likely that the actual number of individual cetaceans exposed to, and potentially affected by, seismic survey sounds was between the minimum and maximum estimates provided below.

Estimates from Direct Observations

The number of cetaceans observed close to the *Ewing* during the SE Caribbean seismic survey provides a minimum estimate of the number of cetaceans potentially affected by seismic sounds. However, this is likely to underestimate the actual number of cetaceans potentially affected. Some animals are likely to have moved away before coming within visual range, and not all of those that remained in the area would have been seen by observers.

Cetaceans Potentially Exposed to Sounds ≥180 dB re 1 µPa (rms).—During this project, nine cetacean groups involving ~245 individual cetaceans were sighted within the safety radii around the operating airguns. In these cases, power downs and in two cases complete shut downs had to be implemented (Table 4.10; also Appendix G). However, only four of these groups are likely to have received airgun pulses at levels ≥180 dB, given their distances from the airgun array. All power downs occurred when the animal(s) were sighted within the safety radius; no power downs occurred before the animal(s) entered the safety radius.

If cetaceans occurred close to the *Ewing* during nighttime airgun operations at the same rate as during daytime operations, then it is likely that nine additional groups occurred close enough such that, if it had been possible to detect these animals, the airguns would have been powered down. However, it is unlikely that all of these (theoretical) additional groups encountered at night would actually have been exposed to ≥180 dB, as explained in the following paragraphs.

The safety radii are the maximum distances from the vessel where sound levels were estimated to diminish to 180 dB re 1 μPa (rms). In deep (>1000 m) water, this maximum distance is likely ~600–1200 m below the water surface (Fig. 3.1, 3.2). However, animals are sighted when they are at the water surface, and sound levels at or near the water surface are considerably lower than levels well below the surface (see Fig. 3.1, 3.2). In many cases it is unknown whether animals seen at the surface were earlier (or later) exposed to the maximum levels that they would receive if they dove deeply. Thus, there are complications in assessing the maximum level to which any specific individual mammal might have been exposed. Other considerations include the following:

- Some cetaceans may have been within the predicted safety radius while underwater and not visible to observers, and subsequently seen outside the safety radius. The direction of movement as noted by MMOs can give some indication of this. Some cetaceans swimming directly away from the vessel or its trackline and not far outside the safety radius may already have been within the safety radius and may have been exposed to sound levels ≥180 dB re 1 µPa. In contrast, cetaceans swimming toward the ship or track when first seen are unlikely to have been within the safety radius prior to being sighted. However, the direction that cetaceans are traveling when sighted at the surface will not always indicate the direction of underwater travel.
- The MMO station on the flying bridge was ~87 m forward of the nearest airgun, in a normal configuration. Therefore, the safety zone was not a circle (or more accurately a half-sphere) with a 900–3500 m radius (depending on water depth) around the observer's station. Rather, this radius should be measured relative to the center of the airgun array. This difference was accounted for in the observer's decisions regarding whether it was necessary to power down or shut down the airguns. For example, during operations with the 20-airgun array in water >1000 m deep, a mammal 900 m forward of the observer's station would be considered to be approaching but not within the precautionary safety radius (900 m). That mammal would actually be 900 m + 87 m (987 m) from the airgun array. However, a mammal in this situation would be closely monitored, and the airguns would be powered down if the mammal was not specifically observed to move away from the vessel track. It should be noted that the 87 m adjustment for the offset between observers and airguns only applied to mammals observed within a narrow band directly forward or astern of the ship, not to those seen to either side of the trackline. All distances to cetaceans reported here refer to the distance from the MMO station, unless otherwise stated, not the center of the airguns.

The predicted 180 dB radii for the 20-airgun array were 900, 1350 and 3500 m, in deep, intermediate and shallow waters, respectively (Table 3.1). Of the nine cetacean groups for which a power down had to be implemented, two groups (pantropical spotted dolphins and spinner dolphins) subsequently approached the safety radius of the one operational airgun (36–108 m, depending on water depth). That resulted in a precautionary complete shut down of the airgun array (Table 4.10). These two groups, as well as two other groups for which complete shut downs were not necessary, were likely exposed to levels ≥180 dB:

- A group of 30 pantropical spotted dolphins was first seen 50 m in front of the *Ewing* (~140 m from the nominal center of the airgun array), traveling at the surface toward the *Ewing* in water >1000 m deep. When first seen, these dolphins were far inside the precautionary 180 dB (rms) radius (0.9 km). The sound level received by the dolphins while they were at the surface during the observation would have been reduced because of near-surface pressure release effects. Thus, even at this close distance they may not have been exposed to received levels ≥180 dB (see Fig. 3.2). However, they were probably exposed to one or more pulses with received levels ≥180 dB (rms) while they were below the surface before they were sighted.
- A group of 80 spinner dolphins was first seen ~2730 m from the *Ewing* in water 360 m deep. The dolphins traveled near the surface toward the vessel and were not sighted again until 26 min later. They then reappeared within ~20 m of the observers (100 m from the nominal center of the airgun array). These dolphins were well within the 180 dB radius, and probably exposed to one

or more pulses with received levels ≥180 dB (rms), while they were below the surface before being resighted.

- Twenty bottlenose dolphins were first sighted 15 m from the observers aboard the *Ewing* (~95 m from the nominal center of the airgun array) which resulted in an immediate power down of the airgun array. These dolphins were seen traveling near the surface in deep water (>3000 m), and subsequently traveled away from the vessel. Thus, a power down to one airgun was performed, but a precautionary shut down was not deemed necessary. Because these dolphins were well within the 180 dB radius, they may have been exposed to one or more pulses with received levels ≥180 dB (rms) while they were below the surface.
- One Bryde's whale was first seen ~1960 m from the *Ewing*, in water 35 m deep. Because this animal was seen well within the 180 dB safety radius for shallow water (3.5 km), it probably was exposed to one or more pulses with received levels ≥180 dB (rms) before the airgun array was powered down.

A group of 55 Atlantic spotted dolphins first sighted ~1000 m outside the 1350-m safety radius was unlikely to have received levels ≥180 dB (rms). The airguns were powered down as soon as the dolphins were resighted ~1340 m away, when they were (nominally) ~10 m within the safety radius appropriate for the intermediate water depth at that location (~150 m). Three additional groups of other species were seen swimming near the surface in water >700 m deep. The sound level received by these cetaceans while at the surface would have been substantially reduced because of near-surface pressure release effects. They these probably were not exposed to seismic pulses with received levels ≥180 dB (rms) before the airguns were powered down.

Had the 3088 km of nighttime seismic surveys (Appendix F-3) been conducted during the day when MMOs could have observed the sea surface out to the safety radius, then we would have expected an additional nine cetacean groups to be sighted within the precautionary safety radii around the operating airguns. Therefore, if all airgun operations had been during daylight hours, we expect that the airguns would have been powered down ~9 additional times due to the presence of cetacean groups within or approaching the precautionary safety radii. In the absence of power downs at night, some (but probably not all) of these nine extra groups could have been exposed to ≥180 dB.

Cetaceans Other Than Delphinids Potentially Exposed to Sounds ≥160 dB re 1 µPa (rms).—Of the 11 visually observed groups of cetaceans that were not identified as delphinids, nine groups were sighted while the airguns were operational. Four of those groups were detected within the ≥180 dB safety radii, as discussed above. The remaining five groups were seen outside of the safety radii but within the ≥160 dB radii of the airgun array (see Appendix G). Thus, nine groups involving a total of ten individuals are considered to have been potentially disturbed by seismic sounds based on the "direct observation" method.

Delphinids Potentially Exposed to Sounds ≥170 dB re 1 µPa (rms).—For delphinids, exposure to airgun sounds with received levels ≥170 dB may be a more appropriate criterion of disturbance than exposure to ≥160 dB. The delphinid hearing system is less sensitive to low-frequency sounds than is the auditory system of large whales (at least baleen whales). Of 11 groups of delphinids observed from the *Ewing*, eight were seen during seismic operations. Five of these were seen within the 180 dB safety radii, two groups were seen outside the safety radii but within the ≥170 dB radii, and one group was seen beyond the ≥170 dB radius but within the 160 dB radius. Thus, seven groups including 273 individual delphinids are considered to have been potentially disturbed by seismic sounds based on the "direct observation" method.

Estimates Extrapolated from Marine Mammal Density

The number of cetaceans sighted during the SE Caribbean survey presumably underestimates the actual number present during the survey because some animals present near the tracklines were not seen by the observers. Animals could not be seen effectively during periods of darkness. Also, sound levels at depth were estimated to be ≥160 dB re 1 μPa (rms) out to quite large radii: 9–12 km, depending on water depth. Those distances are well beyond those at which we could detect even the more conspicuous animals under favorable sighting conditions during daytime. To allow for animals missed during daylight, we corrected our visual observations for missed whales by using correction factors derived from previous studies. To estimate numbers present and potentially affected during nighttime, we assumed that the corrected densities derived for daylight periods also applied to periods of darkness, as described in the "Analyses" section of Chapter 3.

Estimated Densities.—We made 27 sightings of 984 cetaceans during 6050 km of surveys during non-seismic conditions, and 12 sightings of 220 cetaceans during 3068 km of surveys during seismic conditions when the 20-airgun array was operating. These include only sightings and effort when Beaufort Force was ≤5. For intermediate (100–1000 m) and deep (>1000 m) areas, there was sufficient survey effort to provide meaningful estimates of overall density under both non-seismic and seismic conditions (see below). However, in water depths <100 m, we obtained only 25 km and 340 km of observation effort during non-seismic and seismic conditions, respectively. Only one sighting (of a Bryde's whale) was made in water depths <100 m, and that was during seismic conditions. Given the relatively small effort in shallow water, the densities (0.0 and 1.1/1000 km^2 during non-seismic and seismic periods, respectively), were excluded from further analyses. Instead, we used the densities calculated for water depths 100–1000 m to estimate numbers present in shallow water, although based on the very limited survey coverage in shallow water, the densities there may have been lower than those in 100–1000 m.

For *non-seismic conditions* and water depths 100–1000 m, Table 4.11 summarizes the average densities calculated from 16 sightings of 852 cetaceans during 2184 km of survey. The overall estimated density of 82.4 cetaceans/1000 km^2 is probably representative of their overall density during the survey. This density estimate includes allowance for the $f(0)$ and $g(0)$ sightability factors, as described in Chapter 3. The densities for specific species in Table 4.11 (and also in the following Tables) are calculated in a comparable manner, but they only approximate the relative densities in the survey area. The densities for specific species are estimated from small numbers of sightings of groups of greatly varying sizes. Some species that were present during the surveys may not have been sighted. Other species may by chance have been sighted more frequently or in larger groups than would be expected based on their overall distribution and abundance.

For waters >1000 m deep and no seismic, Table 4.12 summarizes the average densities calculated from the 11 sightings of 132 cetaceans during 3841 km of survey. The overall estimated density was 15.9 cetaceans/1000 km^2 or about 19% of the estimated density in water depths 100–1000 m (Fig. 4.4).

For *periods when the 20-airgun array was operating* in water depths of 100–1000 m, Table 4.13 summarizes the average densities calculated from 7 sightings of 183 cetaceans during 905 km of survey. The overall cetacean density of 45.5 cetaceans/1000 km^2 is about 55% of the density in corresponding water depths during periods without seismic (Fig 4.4). This may have been due to movements of cetaceans away from the active seismic vessel, changes in behavior of the animals when exposed to airgun pulses, differences in cetacean abundance between the seismic and non-seismic periods, or a combination of both factors.

TABLE 4.11. Sightings and densities of marine mammals during non-seismic periods in water depths 100–1000 m in the SE Caribbean Sea and adjacent North Atlantic waters during ship surveys, late April to early June 2004. Non-seismic periods are periods before seismic started or periods >6 h after seismic ended. Species in italics are listed under the U.S. ESA as endangered.

Species	Number of sightings	Mean group size	Average density [a] corrected for $f(0)$ and $g(0)$ (# /1000 km^2)	
			Density	CV [b]
Odontocetes				
Physeteridae				
Sperm whale	0	--	0.00	-1.00
Kogia sp	0	--	0.00	-1.00
Ziphiidae				
All beaked whales	0	--	0.00	-1.00
Delphinidae				
Bottlenose dolphin	3	7.7	8.20	0.76
Pantropical spotted dolphin	0	--	0.00	-1.00
Atlantic spotted dolphin	4	40.8	20.64	0.72
Spinner dolphin	0	--	0.00	-1.00
Striped dolphin	0	--	0.00	-1.00
Long-beaked common dolphin	2	320.0	44.84	0.83
All other dolphins	0	--	0.00	-1.00
Unidentified dolphin	2	6.0	4.28	0.83
Other toothed whales	0	--	0.00	-1.00
Short-finned pilot whale	1	8.0	2.85	0.94
Unidentified toothed whale	1	3.0	1.07	0.94
Mysticetes				
Bryde’s whale	0	--	0.00	-1.00
All other mysticetes	0	--	0.00	-1.00
Unidentified whale	3	1.0	0.53	0.76
Total Cetaceans			**82.41**	**0.49**

[a] Values for $f(0)$ and $g(0)$ are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation 0.94 - 0.162log$_e$n from Koski et al. (1998), but likely underestimates the true variability.

TABLE 4.12. Sightings and densities of marine mammals during non-seismic periods in water depths >1000 m in the SE Caribbean Sea and adjacent North Atlantic waters during ship surveys, late April to early June 2004. Non-seismic periods are periods before seismic started or periods >6 h after seismic ended. Species in italics are listed under the U.S. ESA as endangered

Species	Number of sightings	Mean group size	Average density [a] corrected for *f*(0) and *g*(0)(# /1000 km²)	
			Density	CV [b]
Odontocetes				
Physeteridae				
Sperm whale	0	--	0.00	-1.00
Kogia sp	0	--	0.00	-1.00
Ziphiidae				
All beaked whales	0	--	0.00	-1.00
Delphinidae				
Bottlenose dolphin	2	3.5	1.42	0.83
Pantropical spotted dolphin	0	--	0.00	-1.00
Atlantic spotted dolphin	1	11.0	2.23	0.94
Spinner dolphin	0	--	0.00	-1.00
Striped dolphin	1	60.0	4.03	0.94
Long-beaked common dolphin	3	12.7	5.00	0.76
All other dolphins	0	--	0.00	-1.00
Unidentified dolphin	3	3.3	2.03	0.76
Other toothed whales	0	--	0.00	-1.00
Short-finned pilot whale	1	6.0	1.22	0.94
Unidentified toothed whale	0	--	0.00	-1.00
Mysticetes				
Bryde's whale	0	--	0.00	-1.00
All other mysticetes	0	--	0.00	-1.00
Unidentified whale	0	--	0.00	-1.00
Total Cetaceans			**15.93**	**0.55**

[a] Values for *f*(0) and *g*(0) are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation $0.94 - 0.162\log_e n$ from Koski et al. (1998), but likely underestimates the true variability.

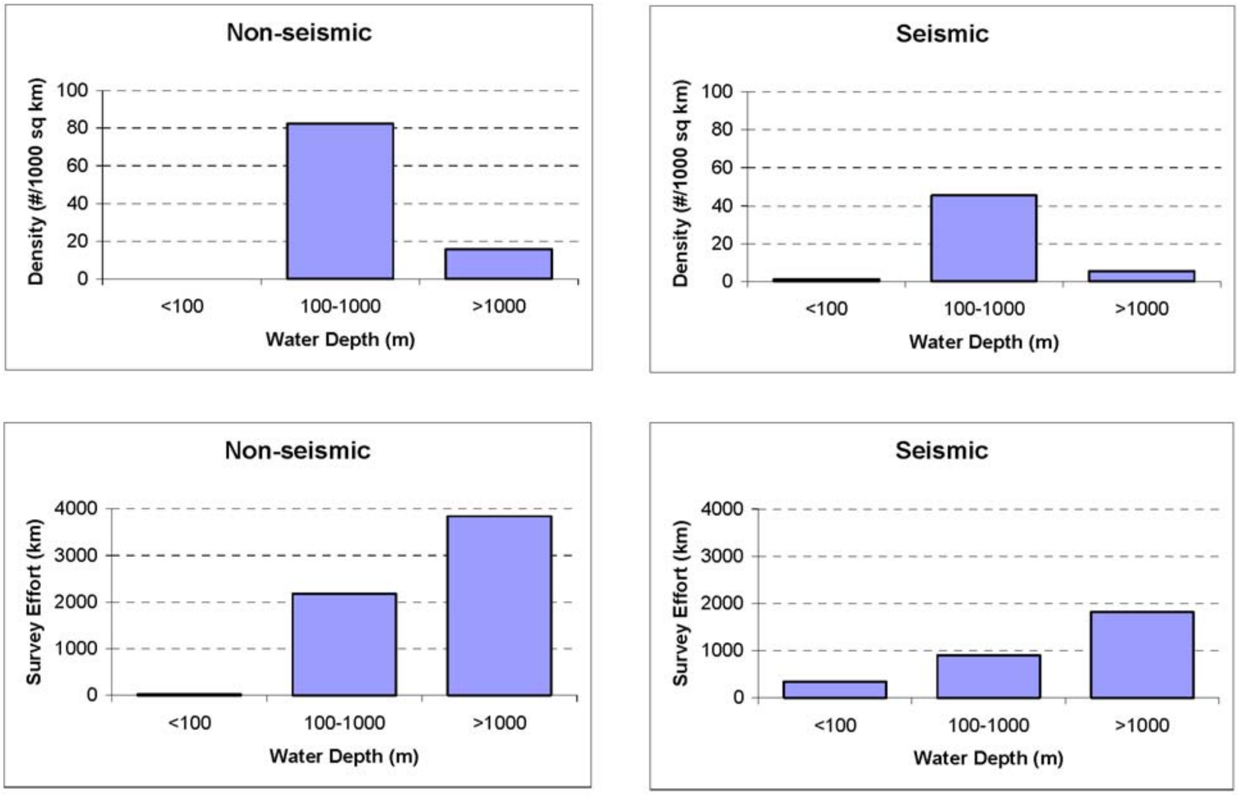

FIGURE 4.4. Densities of all cetaceans (upper panels) and survey effort (lower panels) during seismic and non-seismic survey periods.

For waters >1000 m deep and the 20-airgun array operating, Table 4.14 summarizes the average densities calculated from four sightings of 36 cetaceans during 1822 km of survey. As was the case in non-seismic periods, the overall cetacean density in water >1000 m deep (5.6 cetaceans/1000 km^2) was much lower (~1/8th) than in water 100–1000 m. Also, apparent densities during seismic periods were again lower (35%) than those during periods without seismic.

The consistent tendencies for lower densities in deep water than in intermediate depths, and with seismic operations than without seismic operations, suggest that these effects are real. During seismic periods, some cetaceans probably either moved away from the approaching source vessel, beyond detection range of the observers, or changed their behavior in a way that made them less conspicuous to the observers. The differences could be a combination of both of these hypothesized effects. However, the observed differences (especially in intermediate depths) are also well within the normal range of variation that might be expected for the study area. One cannot be certain from a single uncontrolled study of this type what fraction of the apparent effect is attributable to avoidance or behavioral responses as opposed to natural variation.

***Estimating Numbers of Cetaceans Exposed*.—**We used two methods to estimate the area that was potentially ensonified to ≥160 or ≥170 dB re 1 μPa (rms). Separate calculations were done for areas with water depth <100, 100–1000 and >1000 m because of the different sound propagation properties in the different water depths (see Table 3.1) and because of different cetacean densities, at least in intermediate vs. deep water (see Fig. 4.4 and Tables 4.11 to 4.14). Because there was insufficient effort in shallow water to estimate the densities of cetaceans there, we used densities from water depths 100–1000 m in our estimates of numbers exposed in shallow water.

TABLE 4.13. Sightings and densities of marine mammals during seismic periods in water depths 100–1000 m in the SE Caribbean Sea and adjacent North Atlantic waters during ship surveys, late April to early June 2004. Seismic periods are periods when the full 20-airgun array was operating. Species in italics are listed under the U.S. ESA as endangered.

Species	Number of sightings	Mean group size	Average density [a] corrected for *f* (0) and *g* (0)(# /1000 km^2)	
			Density	CV [b]
Odontocetes				
Physeteridae				
Sperm whale	1	6	2.67	0.94
Kogia sp	0	--	0.00	-1.00
Ziphiidae				
All beaked whales	0	--	0.00	-1.00
Delphinidae				
Bottlenose dolphin	0	--	0.00	-1.00
Pantropical spotted dolphin	0	--	0.00	-1.00
Atlantic spotted dolphin	1	55.0	15.68	0.94
Spinner dolphin	1	80.0	12.91	0.94
Striped dolphin	0	--	0.00	-1.00
Long-beaked common dolphin	0	--	0.00	-1.00
All other dolphins	0	--	0.00	-1.00
Unidentified dolphin	2	19.0	12.56	0.83
Other toothed whales	0	--	0.00	-1.00
Short-finned pilot whale	0	--	0.00	-1.00
Unidentified toothed whale	0	--	0.00	-1.00
Mysticetes				
Bryde's whale	1	2	0.86	0.94
All other mysticetes	0	--	0.00	-1.00
Unidentified whale	1	2.0	0.86	0.94
Total Cetaceans			**45.54**	**0.60**

[a] Values for *f* (0) and *g* (0) are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation $0.94 - 0.162\log_e n$ from Koski et al. (1998), but likely underestimates the true variability.

TABLE 4.14. Sightings and densities of marine mammals during seismic periods in water depths >1000 m in the SE Caribbean Sea and adjacent North Atlantic waters during ship surveys, late April to early June 2004. Seismic periods are periods when the full 20-airgun array was operating. Species in italics are listed under the U.S. ESA as endangered.

Species	Number of sightings	Mean group size	Average density [a] corrected for $f(0)$ and $g(0)$ (# /1000 km^2)	
			Density	CV [b]
Odontocetes				
Physeteridae				
Sperm whale	2	2.5	1.11	0.83
Kogia sp	0	--	0.00	-1.00
Ziphiidae				
All beaked whales	0	--	0.00	-1.00
Delphinidae				
Bottlenose dolphin	0	--	0.00	-1.00
Pantropical spotted dolphin	1	30	4.25	0.94
Atlantic spotted dolphin	0	--	0.00	-1.00
Spinner dolphin	0	--	0.00	-1.00
Striped dolphin	0	--	0.00	-1.00
Long-beaked common dolphin	0	--	0.00	-1.00
All other dolphins	0	--	0.00	-1.00
Unidentified dolphin	0	--	0.00	-1.00
Other toothed whales	0	--	0.00	-1.00
Short-finned pilot whale	0	--	0.00	-1.00
Unidentified toothed whale	0	--	0.00	-1.00
Mysticetes				
Bryde's whale	0	--	0.00	-1.00
All other mysticetes	0	--	0.00	-1.00
Unidentified whale	1	1.0	0.21	0.94
Total Cetaceans			**5.57**	**0.72**

[a] Values for $f(0)$ and $g(0)$ are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation $0.94 - 0.162\log_e n$ from Koski et al. (1998), but likely underestimates the true variability.

In the first method, the total length of the seismic survey lines was multiplied by the width of the zone exposed to the relevant sound level: ≥160 dB for mysticetes and odontocetes other than delphinids, and ≥170 dB for delphinids, i.e., track length × [160 or 170 dB radius × 2]. When multiplied by the density of marine mammals in the area, this method produces an estimate of the *total **number of exposures** of marine mammals to sounds ≥160 or ≥170 dB re 1 µPa*. This calculation was done separately for the different water depth strata, given the effect of water depth on both the cetacean densities and on the 160 and 170 dB distances.

Some of the survey lines in the study area were spaced close to one another or crossed each other (Fig. 4.2). Thus, there was overlap in the 160 (and 170) dB zones around adjacent or crossing seismic lines. In this situation, the total area exposed to ≥160 or 170 dB (in some locations repeatedly) is smaller than that calculated from the total length of trackline as described in the previous paragraph. In this situation, the estimated number of individual exposures will probably include repeated exposures to some of the same marine mammals, and will exceed the ***number of different individuals exposed** to sounds ≥160 or ≥170 dB re 1 µPa at least once*. A minimum estimate[2] of the latter number can be derived by determining the total area that was exposed to the relevant sound level (≥160 or 170 dB) one or more times during the season, and multiplying that area by the estimated density of mammals. The total area exposed was estimated using GIS techniques and was calculated for each of the three water depth categories separately.

Both estimates, i.e., "number of exposures" and "number of individuals exposed", were derived for seals exposed to strong airgun sounds in the Alaskan Beaufort Sea (Harris et al. 2001; Moulton and Lawson 2002). Likewise, both procedures were used to estimate the number of cetaceans exposed to strong airgun sounds during L-DEO projects in the tropical Pacific Ocean (Smultea and Holst 2003) and in the Norwegian Sea (McLean and Haley 2003). In subsequent subsections, both approaches are applied to estimate numbers of cetaceans potentially affected by the present seismic survey.

Also, estimates are derived from density figures based on two sets of observations: those during non-seismic periods, and (separately) those during seismic periods. Both estimates are meaningful, but represent different things:

- The former are calculated from combined visual sightings by MMOs aboard the *Ewing* during non-seismic periods, and aboard the *SJII*. Those densities represent the number of mammals expected to occur "naturally" within the area where disturbance is predicted (based on the 160 or 170 dB criteria).
- The latter densities are calculated from visual sightings by MMOs aboard the *Ewing* during seismic periods. Those densities represent the minimum[3] number of mammals that apparently remained within the area exposed to strong airgun pulses, i.e., received levels ≥160 jor 170 dB (rms).

***Estimates Based on Densities during Non-seismic Periods*.—**"Corrected" densities of cetaceans observed during non-seismic periods in water depths 100–1000 and >1000 m are presented above in Tables 4.11

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[2] This is a minimum estimate because it does not allow for movements of the animals within the study area during the course of the study.

[3] These are minimum estimates because they assume that densities calculated from sighting rates within visual range of the ship during airgun operations were representative of the entire zone out to the 160 or 170 dB radius. We expect that there is stronger avoidance of waters within visual range than of waters beyond visual range but still within the 160 or 170 dB distance. Thus, the estimated density during seismic operations probably underestimates the actual density at those times within the full area out to the 160 or 170 dB radius.

and 4.12. These corrected densities were used to estimate the number of cetaceans that were potentially disturbed by seismic operations. Since the effort and sightings in water depths <100 m were too low to compute reliable densities, we applied the densities calculated in water depths 100–1000 m to areas ensonified that were <100 m deep. In water <100 m deep, an area of ~15,201 km^2 was ensonified to ≥160 dB during seismic operations with the 20-airgun array and ~93 km^2 was ensonified during seismic operations with a single air gun. These areas were estimated from the vessel tracklines, which were entered into a GIS, along with the appropriate 160 dB distances. The GIS was used to "draw" a 9.0, 10.0, or 12.0 km buffer (in water depths <100 m, 100–1000 m, or >1000 m, respectively) around each seismic line (for the 20-airgun array), and then to determine the total area within the buffers. This process was repeated based on the much smaller radii applicable to the single airgun (Table 3.1). The total for each water depth includes all airgun operations, day or night. Thus, the total area where cetaceans were potentially affected in water <100 m deep was **15,294 km^2** (15,201+93). The estimated numbers of exposures to sounds ≥160 dB re 1 μPa in waters <100 m deep, using the "corrected" densities in Table 4.11 and the area calculated above, are shown in Table 4.15. This process was repeated for the two deeper water depth categories, and thence the number of exposures in all water depths combined (Table 4.15). Because nighttime and daytime surveys are included in the above estimates of the area exposed to ≥160 dB, the estimates allow for the number of exposures of cetaceans to received levels ≥160 dB during night and day.

As noted above, some of the seismic lines were close enough to (or crossed) other seismic lines such that the zones exposed to 160 dB around those lines overlapped and were exposed more than once (Fig. 4.1). Thus, some cetaceans may have been exposed to ≥160 dB re 1 μPa (rms) on more than one occasion. The total area exposed to ≥160 dB on one or more occasions was determined by using a MapInfo GIS system. This showed that **12,440 km^2** of water surface was within the nominal ≥160 dB zone in water <100 m deep on one or more occasions during the project, as compared to the 15,294 km^2 calculated simply from the lengths of the seismic lines. Therefore, a *minimum* estimate of the number of *different individuals that might have been exposed* to ≥160 dB is calculated by multiplying the corrected density by the area exposed to ≥160 dB at least once, 12,440 km^2. Those minima are also shown on the right side of Table 4.15.

This latter estimate would be reasonable if the mammals remained stationary throughout the study, but this is unlikely. Thus, the actual number of individuals exposed to ≥160 dB re 1 μPa (rms) would be expected to be somewhere between the estimates shown in Table 4.15.

On the average, delphinids may be disturbed only if exposed to received levels of airgun sounds ≥170 dB re 1 μPa (rms). If so, then the estimated number of exposures of delphinids would be ~25 to 50% of the estimates for ≥160 dB (see parenthetical values in Table 4.15). This is a result of the smaller 170 dB radii as compared with 160 dB radii. The specific estimates depend on the water depth and whether or not the area ensonified includes or excludes overlap. Overall, based on densities of cetaceans seen during non-seismic periods, the number of delphinid exposures to ≥170 dB (1620) would be ~35% of those to ≥160 dB (4634), given the total areas determined to be exposed to ≥170 dB vs. ≥160 dB (29,825 km^2 vs. 96,206 km^2). The number of delphinid individuals exposed to ≥170 dB would be 37% of those exposed to ≥160 dB (Table 4.15.)

***Estimates Based on Densities during Seismic Periods*.—**Densities observed near the survey vessel during seismic periods were lower than those during non-seismic periods. As discussed above, this may have been due to movements of cetaceans away from the active seismic vessel, reduced sightability during exposure to airgun pulses, differences in cetacean distribution and abundance between the two survey periods, or a combination of factors. The estimated numbers of exposures and the minimum numbers of individual cetaceans that may have been exposed to seismic sounds ≥160 dB, and for delphinids, ≥170 dB, are shown in Table 4.16.

TABLE 4.15. Estimated numbers of exposures and estimated minimum numbers of individual marine mammals that would have been exposed to seismic sounds ≥160 dB (and ≥170 dB) in the SE Caribbean Sea and adjacent North Atlantic waters **if no animals had moved away** from the active seismic vessel, late April to early June 2004. The sound sources were a 20-airgun array with a total volume of 6947 in^3 and a single airgun with a volume of 80 in^3. Received levels of airgun sounds are expressed in dB re 1 μPa (rms, averaged over pulse duration). Species in italics are listed under the U.S. ESA as endangered.

Species/species group	**Numbers of exposures in areas of**				**Minimum number of individuals in areas of**			
Water depth (m)	**<100**	**100-1000**	**>1000**	**All depths**	**<100**	**100-1000**	**>1000**	**All depths**
Area in km^2 ensonified to ≥160 dB (≥170 dB)	15,294 (7718)	31,351 (9,648)	49,561 (12,459)		12,440 (6630)	26,584 (8470)	38,440 (10,427)	
Odontocetes								
Physeteridae								
Sperm whale	0	0	0	0	0	0	0	0
Kogia sp	0	0	0	0	0	0	0	0
Ziphiidae								
All beaked whales	0	0	0	0	0	0	0	0
Delphinidae								
Bottlenose dolphin	125 (63)	257 (79)	70 (18)	453 (160)	102 (54)	218 (69)	55 (15)	375 (139)
Pantropical spotted dolphin	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()
Atlantic spotted dolphin	316 (159)	647 (199)	111 (28)	1073 (386)	257 (137)	549 (175)	86 (23)	891 (335)
Spinner dolphin	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()
Striped dolphin	0 ()	0 ()	200 (50)	200 (50)	0 ()	0 ()	155 (42)	155 (42)
Long-beaked common dolphin	686 (346)	1406 (433)	248 (62)	2339 (841)	558 (297)	1192 (380)	192 (52)	1942 (729)
All other dolphins	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()
Unidentified dolphin	65 (33)	134 (41)	101 (25)	300 (100)	53 (28)	114 (36)	78 (21)	245 (86)
Other toothed whales	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()
Short-finned pilot whale	44 (22)	89 (28)	60 (15)	194 (65)	35 (19)	76 (24)	47 (13)	158 (56)
Unidentified toothed whale	16 (8)	34 (10)	0 ()	50 (19)	13 (7)	28 (9)	0 ()	42 (16)
Mysticetes								
Bryde's whale	0	0	0	0	0	0	0	0
All other mysticetes	0	0	0	0	0	0	0	0
Unidentified whale	8	17	0	25	7	14	0	21
Total Cetaceans				**4634 (1620)**				**3828 (1402)**

[a] Values for $f(0)$ and $g(0)$ are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation 0.94 - $0.162\log_e n$ from Koski et al. (1998), but likely underestimates the true variability.

TABLE 4.16. Estimated numbers of exposures and estimated minimum numbers of individual marine mammals that were exposed to seismic sounds ≥160 dB (≥170 dB) in the SE Caribbean Sea and adjacent North Atlantic waters during seismic survey periods, late April to early June 2004. The sound sources were a 20-airgun array with a total volume of 6947 in^3 and a single airgun with a volume of 80 in^3. Received levels of airgun sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration). Species in italics are listed under the U.S. ESA as endangered.

Species/species group	**Numbers of exposures in areas of**				**Minimum number of individuals in areas of**			
Water depth (m)	**<100**	**100-1000**	**>1000**	**All depths**	**<100**	**100-1000**	**>1000**	**All depths**
Area in km^2 ensonified to ≥160 dB (≥170 dB)	15,294 (7718)	31,351 (9,648)	49,561 (12,459)		12,440 (6630)	26,584 (8470)	38,440 (10,427)	
Odontocetes								
Physeteridae								
Sperm whale	41	84	55	180	33	71	43	147
Kogia sp	0	0	0	0	0	0	0	0
Ziphiidae								
All beaked whales	0	0	0	0	0	0	0	0
Delphinidae								
Bottlenose dolphin	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()
Pantropical spotted dolphin	0 ()	0 ()	211 (53)	211 (53)	0 ()	0 ()	163 (44)	163 (44)
Atlantic spotted dolphin	240 (121)	492 (151)	0 ()	731 (272)	195 (104)	417 (133)	0 ()	612 (237)
Spinner dolphin	197 (100)	405 (125)	0 ()	602 (224)	161 (86)	343 (109)	0 ()	504 (195)
Striped dolphin	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()
Long-beaked common dolphin	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()
All other dolphins	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()
Unidentified dolphin	192 (97)	394 (121)	0 ()	586 (218)	156 (83)	334 (106)	0 ()	490 (190)
Other toothed whales	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()
Short-finned pilot whale	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()
Unidentified toothed whale	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()
Mysticetes								
Bryde's whale	13	27	0	40	11	23	0	34
All other mysticetes	0	0	0	0	0	0	0	0
Unidentified whale	13	27	10	51	11	23	8	42
Total Cetaceans				**2400 768**				**1991 666**

[a] Values for *f* (0) and *g* (0) are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation 0.94 - 0.162$\log_e$n from Koski et al. (1998), but likely underestimates the true variability.

Cetaceans Potentially Exposed to Sounds ≥180 dB.—MMOs watched for cetaceans approaching the seismic vessel during all daylight periods while the airguns were firing as part of the monitoring and mitigation procedures. The predicted distances at which sound levels declined to 180 dB re 1 μPa (rms) were 900 m in water depths >1000 m, 1350 m in water depths 100–1000 m, and 3500 m in water depths <100 m (Table 3.1). In the two deeper strata, most cetaceans that were at the surface within the 180 dB radius during daylight observation periods would have been seen by the observers. Based on the densities of cetaceans observed during non-seismic periods, 308 cetacean exposures and 276 individuals would have been expected to have occurred within the 180 dB radius of the airguns (Table 4.17). These estimates are similar to the estimate of 245 individuals, based on direct observation (see *Estimate from Direct Observation* above). However, the former estimates apply to day and night, whereas the latter estimate applied only to daylight seismic operations.

Summary of Exposure Estimates.—Estimates of the numbers of exposures to strong sounds are considered *maximum* estimates of the number of mammals exposed. This assumes that repeated exposures of some of the same animals are counted separately, with no allowance for overlapping survey lines. Based on densities of cetaceans observed during non-seismic periods, 4634 cetacean exposures were estimated to have occurred during seismic surveys in the SE Caribbean and adjacent North Atlantic water during mid-April to early June 2004 (Table 4.15). The overall estimate of exposures is about 25% of the take estimated in the IHA Application. There are two reasons for this difference. First, the requested take authorization was based on ***maximum*** numbers of cetaceans that would be expected in the survey area during the survey period. Therefore, this approach tends to overestimate the number that is ***likely*** to be there. Secondly, the earlier survey data of Swartz and Burks (2000) and Swartz et al. (2001), from which the take requests were calculated, were primarily from water depths <1000 m. The data from this study included considerable effort in water depths >1000 m where densities were 12–19% of those in shallower areas. When the density data from the earlier study were used to estimate densities in >1000 m, the estimates were too high.

The overall estimate of the number of exposures should be fairly reliable because it is based on moderate numbers of sightings in each of the two water depths where the majority of the seismic activity occurred. However, the estimates for specific species may over- or underestimates, or may accurately represent the densities that were actually present during the survey. They are based on zero-to-few sightings and are subject to random sampling error.

Maximum estimates of the number of potential exposures of delphinids to received levels of ≥170 dB based on density data from non-seismic periods are also shown in Table 4.15. Delphinids are expected to be less responsive to the low-frequency sounds characteristic of seismic pulses than are mysticetes and, perhaps, some large odontocetes. The delphinid auditory system is less sensitive to low frequency sounds than is assumed for mysticetes. These maximum estimates of the number of delphinid exposures to ≥170 dB are considerably lower than best estimates presented in the IHA Application, for the same reasons described above.

Summary of Minimum Numbers Exposed.—Minimum estimates of the number of different individual animals exposed to received levels of ≥160 dB and ≥170 dB were derived by multiplying the densities observed during non-seismic periods during this study by the actual surface areas exposed to ≥160 or ≥170 dB on one or more occasions (Table 4.15). These estimates would be reasonable if the mammals remained stationary throughout the SE Caribbean study, but they do not. Thus, the resulting numbers are considered *minimum* estimates. The IHA Application and EA did not directly consider minimum estimates of the number of different individual cetaceans that might be exposed to strong airgun sound, and therefore these estimates are lower than those predicted prior to the survey, which were based on the anticipated number of exposures.

TABLE 4.17. Estimated numbers of exposures and estimated minimum numbers of individual cetaceans that would have been exposed to seismic sounds **≥180 dB** in the SE Caribbean Sea and adjacent North Atlantic waters if they had not moved away from the seismic vessel, late April to early June 2004. Densities are from observations during seismic periods. The sound sources were a 20-airgun array with a total volume of 6947 in^3 and a single airgun with a volume of 80 in^3. Received levels of airgun sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration). Species in italics are listed under the U.S. ESA as endangered.

Species/species group	Numbers of exposures in areas of				Minimum number of individuals in areas of			
Water depth (m)	**<100**	**100-1000**	**>1000**	**All depths**	**<100**	**100-1000**	**>1000**	**All depths**
Area in km^2 ensonified to ≥180 dB (≥190 dB)	15,294	31,351	49,561		12,440	26,584	38,440	
Odontocetes								
Physeteridae								
Sperm whale	9	8	5	21	8	7	4	19
Kogia sp	0	0	0	0	0	0	0	0
Ziphiidae								
All beaked whales	0	0	0	0	0	0	0	0
Delphinidae								
Bottlenose dolphin	0	0	0	0	0	0	0	0
Pantropical spotted dolphin	0	0	17	17	0	0	15	15
Atlantic spotted dolphin	53	45	0	98	47	41	0	88
Spinner dolphin	43	37	0	81	39	34	0	73
Striped dolphin	0	0	0	0	0	0	0	0
Long-beaked common dolphin	0	0	0	0	0	0	0	0
All other dolphins	0	0	0	0	0	0	0	0
Unidentified dolphin	42	36	0	79	38	33	0	71
Other toothed whales	0	0	0	0	0	0	0	0
Short-finned pilot whale	0	0	0	0	0	0	0	0
Unidentified toothed whale	0	0	0	0	0	0	0	0
Mysticetes								
Bryde's whale	3	2	0	5	3	2	0	5
All other mysticetes	0	0	0	0	0	0	0	0
Unidentified whale	3	2	1	6	3	2	1	6
Total Cetaceans				**308**				**276**

[a] Values for $f(0)$ and $g(0)$ are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation 0.94 - 0.162log$_e$n from Koski et al. (1998), but likely underestimates the true variability.

Summary and Conclusions

Results of L-DEO's SE Caribbean marine mammal monitoring program provide the largest systematically collected database in the SE Caribbean Sea. Over 900 h and >10,000 km of visual observation effort, and >800 h and >7300 km of acoustic monitoring effort were conducted. An estimated total of 1294 cetaceans were observed in 47 groups during the SE Caribbean survey. This total includes one dead floating and decomposing fin whale sighted by MMOs from the *SJII*. The whale's death was not related to the *Ewing*'s seismic operations. This conclusion was supported by an independent review by a panel of cetacean experts, including NMFS and the Regional Coordinator of CIC in Venezuela. No injured animals potentially associated with the operations were sighted.

Ten different cetacean species were identified during the study. Unidentified whales and unidentified dolphins were the most commonly seen groups. However, the long-beaked common dolphins (n = 734) and Atlantic spotted dolphins (n = 229) were the most numerous cetaceans given their larger average group sizes. No pinnipeds or sirenians were seen during the survey.

A total of 78 acoustic encounters with calling cetaceans were detected from the *Ewing* during nearly 24 h/day of PAM. All 66 acoustic-only detections were unidentified dolphins (n = 61) or sperm whales (n = 5). Most (99% of 78) acoustic encounters occurred during seismic periods. Acoustic encounters with delphinids occurred more frequently at night than during the day. Delphinids may call more frequently at night to coordinate foraging strategies associated with the deep scattering layer, as has been reported for delphinids in the north-central Gulf of Mexico (Stienessen 1998). Twelve of the 21 cetacean groups sighted from the *Ewing* were matched with concurrent acoustic encounters involving 7 different odontocete species. No mysticete vocalizations were detected during PAM from the *Ewing*, although 7 Bryde's, unidentified mysticete, or other large whales were seen.

Results of this program confirm that no one monitoring or mitigation measure is entirely effective in detecting marine mammals or avoiding exposure to strong airgun sounds. Combined use of visual and passive acoustic monitoring techniques increased the likelihood of detecting cetaceans during the *Ewing* seismic operations in the SE Caribbean seismic study. The SE Caribbean cruise was the first operational implementation of PAM during an L-DEO seismic survey. However, as implemented in this cruise, PAM was of little direct use in implementing mitigation measures, as distance to the detected cetaceans typically could not be determined from acoustic data alone. Operational restrictions associated with the *Ewing*'s towed airgun array and 6-km-long hydrophone streamer prevented the maneuvering that would be necessary to determine distances via a towed hydrophone array such as the one used here. In addition, it is difficult to ascertain whether subsequent acoustic detections are of the same individual, particularly in large, spread-out groups typical of delphinids. However, PAM detected odontocetes much more frequently than did visual techniques during daytime-only periods and especially at night, when visual observations are essentially ineffective. Overall, the results indicate that different monitoring and mitigation techniques can be complementary. In judiciously-chosen combinations, they can substantially reduce the likelihood of biologically-significant effects.

The results indicate that seismic sounds displaced or deterred cetaceans from approaching the *Ewing*, and/or affected their behavior. Apparent densities of cetaceans during seismic periods were 35–55% of those during non-seismic periods. Also, cetaceans, and especially delphinids, tended to be sighted closer to the observation vessel during non-seismic vs. seismic periods. Delphinids frequently approached and sometimes bow-rode the *SJII* during non-seismic periods; however, they were never seen bow-riding the *Ewing* during seismic (or non-seismic) operations and only infrequently approached it. In contrast to visual results, acoustic detection rates of calling delphinids were considerably higher during seismic vs. non-seismic periods. This could suggest that delphinids called more frequently while the airguns were on. It is possible that the calls increased in response to, or to "compensate for", the sound created by the airguns.

During this project, nine cetacean groups involving ~245 individual cetaceans were sighted within the 180 dB safety radii around the operating airguns; however, only four of these groups are likely to have actually received airgun sounds ≥180 dB re 1 μPa (rms). Seven of eight groups of delphinids were sighted within the 170 dB radius of the airguns. They were potentially exposed to sounds that might have affected their behavior. All nine groups of other cetaceans were sighted within the 160 dB radius and might have been exposed to sounds that could have affected their behavior.

Densities of cetaceans were calculated based on survey data from seismic and non-seismic periods and for water depths 100–1000 m and >1000 m (Beaufort states >5 excluded). A total of 27 sightings of 984 cetaceans were made during 6050 km of surveys during non-seismic conditions. Twelve sightings of 220 cetaceans were made during 3068 km of surveys during seismic conditions. Densities in areas >1000 m deep were 12 to 19% of those in areas 100–1000 m deep during seismic and non-seismic periods, respectively. During seismic periods, apparent densities were 55% and 35% of those during non-seismic periods in water depths 100–1000 m and >1000 m, respectively.

Minimum and maximum estimates of numbers of cetaceans exposed to strong airgun sounds are shown in Table 4.18 based on the densities recorded during seismic and non-seismic periods. Also shown, for comparison, are the numbers of "harassment takes" that were estimated by L-DEO prior to the survey and presented in the IHA application. Except for sperm whales, all estimates based on actual density data are lower than the "harassment takes" that were calculated prior to the survey. The estimates based on sightings during seismic and non-seismic periods are 0 and 147 individuals, respectively, whereas the estimate calculated prior to the survey was 117. The best estimate, based on sighting data, of the numbers of sperm whales exposed to strong airgun sounds is somewhere between 0 and 147 individuals.

The numbers of "exposures" and of "individuals exposed" estimated from the survey data during seismic periods were lower than the estimates based on survey data acquired during non-seismic periods. This suggests that some cetaceans avoided the seismic vessel before being seen by the observers, or changed their behavior in ways that made them less conspicuous to observers. However, considerable variation in distribution and density would be expected in the absence of seismic. Thus, it is not known for certain how much of the apparent effect was attributable to seismic. In all cases, the estimated exposure was less than the predicted "harassment take".

A further complication in estimating the number of cetaceans potentially disturbed by seismic survey sounds is that the ≥160 and ≥170 dB criteria are approximations. Not all marine mammals, and particularly not all odontocetes, change their behavior when exposed to these sound levels. Many of the changes in behavior that do occur are transitory, difficult to detect without sophisticated monitoring and statistical techniques, and probably of no biological significance. Conversely, some individuals (at least in the case of baleen and apparently sperm whales) alter their behavior when received levels of airgun pulses are lower than 160 dB re 1 µPa (rms) (see reviews in LGL Ltd. 2003a,b; Gordon et al. 2004).

Ultimately, results suggest that the apparent densities of some cetaceans in the SE Caribbean study area during mid April to early June 2004 were lower near the operating seismic vessel than predicted by the surveys during the non-seismic periods. The lower densities could in part be due to day-to-day changes in distribution and abundance. However, a variety of types of evidence suggest that the seismic surveys had localized effects on cetacean distribution and behavior generally consistent with those expected based on previous studies (Richardson et al. 1995; Gordon et al. 2004). In any event, the number of cetaceans potentially affected by L-DEO's SE Caribbean Sea project was lower than initially predicted. The effects were probably localized and transient, with no significant impact on either individual cetaceans or their populations.

TABLE 4.18. Maximum (exposures) and minimum (individuals) estimates of the number of cetaceans exposed to ≥160 dB (or for delphinids, ≥170 dB) re 1 µPa (rms), based on observed densities during non-seismic and seismic periods during surveys in the SE Caribbean Sea and adjacent North Atlantic Ocean. Also shown is the "harassment take" authorized by NMFS under the IHA.

	Estimated numbers exposed to ≥160 dB re 1 µPa (rms) (and ≥170 dB) and based on observations during seismic periods		Estimated numbers exposed to ≥160 dB re 1 µPa (rms) (and ≥170 dB) based on observations during non-seismic periods		Authorized take
	Exposures	**Individuals**	**Exposures**	**Individuals**	
Odontocetes					
Physeteridae					
Sperm whale	180	147	0	0	117
All Kogia	0	0	0	0	4
Ziphiidae					
All beaked whales	0	0	0	0	30
Delphinidae					
Bottlenose dolphin	0 ()	0 ()	453 (160)	375 (139)	4982
Pantropical spotted dolphin	211 (53)	163 (44)	0 ()	0 ()	1265
Atlantic spotted dolphin	731 (272)	612 (237)	1073 (386)	891 (335)	3070
Spinner dolphin	602 (224)	504 (195)	0 ()	0 ()	145
Striped dolphin	0 ()	0 ()	200 (50)	155 (42)	145
Long-beaked common dolphin	0 ()	0 ()	2339 (841)	1942 (729)	5551
All other dolphins	0 ()	0 ()	0 ()	0 ()	2271
Unidentified dolphins	586 (218)	490 (190)	300 (100)	245 (86)	
Other toothed whales	0 ()	0 ()	0 ()	0 ()	364
Short-finned pilot whale	0 ()	0 ()	194 (65)	158 (56)	91
Unidentified toothed whale	0 ()	0 ()	50 (19)	42 (16)	
Mysticetes					
Bryde's whale	40	34	0	0	361
All other mysticetes	0	0	0	0	89
Unidentified whale	51	42	25	21	
All Cetaceans	**2400 (768)**	**1991 (666)**	**4634 (1620)**	**3828 (1402)**	**18485**

5. SEA TURTLES

Introduction

This chapter describes the results of the sea turtle monitoring program. The chapter begins with a review of the status of sea turtles occurring in the study area in the SE Caribbean Sea, and presents the results of the sea turtle monitoring program. The chapter ends with a brief summary and conclusions section. An overview of program operations was provided in Chapter 2, and the mitigation and monitoring programs were described in Chapter 3.

Status of Sea Turtles in the Area

Several species of sea turtles could occur in the study area in the SE Caribbean Sea. These include the loggerhead turtle (*Caretta caretta*), green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricata*), leatherback sea turtle (*Dermochelys coriacea*), olive ridley turtle (*Lepidochely olivacea*), and Kemp's ridley turtle (*L. kempii*). The last of these is uncommon in the area.

In the study area, the loggerhead, green, and olive ridley sea turtle are currently listed as Threatened Species under the U.S. ESA, and the leatherback, Kemp's ridley, and hawksbill sea turtles are listed as Endangered Species. The World Conservation Union lists Kemp's ridley, leatherback and hawksbill sea turtles as Critically Endangered, and loggerhead, green, and olive ridley sea turtles as Endangered.

Sea turtles spend most of their time at sea, and generally only return to land to nest. Nesting areas of sea turtles occur in or near the study area in the SE Caribbean Sea.

- Loggerhead turtles are known to nest in Venezuela, Aruba, the Netherlands Antilles, and Barbados (although rarely) from mid-May to mid-July. Loggerheads have also occasionally been observed feeding in waters near Venezuela, St. Lucia, St. Vincent, the Grenadines, and Barbados.
- Green sea turtles also nest along the coast of Venezuela, the Netherlands Antilles, Barbados, Aruba, St. Vincent, the Grenadines, and St. Lucia. The peak breeding season in the area generally occurs from April to October (EuroTurtle 2001). However, adult green turtles are present in these areas year-round.
- Hawksbill turtles nest near St. Vincent, the Grenadines, Dominica, Trinidad, St. Lucia, Aruba, Barbados and the Netherlands Antilles (Curaçao, Bonaire, St. Maarten, St. Eustatius, Saba) during all months except February and March; however, a peak in nesting activity occurs in June and August.
- Olive ridley turtles also nest along the north coast of Venezuela (Sternberg 1981), and non-nesting individuals occur regularly near Isla Margarita and Trinidad.
- Leatherbacks nest in the Venezuela and the Caribbean islands (St. Lucia, St. Vincent, the Grenadines, the Netherlands Antilles and Barbados) from March to July.

Monitoring and Mitigation

Monitoring and mitigation requirements for sea turtles, as identified in the IHA (Appendix A), were summarized in Chapter 3 along with those for marine mammals. Monitoring and mitigation measures specifically implemented for sea turtles are described below.

Observers diligently monitored for sea turtles near the *Ewing* seismic source vessel during all daytime airgun operations and during any nighttime periods (e.g., ramp ups) as required by the IHA. The IHA required airguns to be powered down (or shut down if necessary) if a turtle was seen within the safety radius. The safety radius was not specifically defined in the IHA, but was taken to be the 180 dB re 1 μPa (rms) radius applicable to the water depth where the airguns were operating at the time (Table 3.1). The SE Caribbean study was the first L-DEO seismic cruise during which this mitigation measure was required by the IHA. During previous L-DEO cruises, the IHA required that airgun operations be delayed if a turtle was seen within the safety radius just before the planned onset of airgun operations. However, it did not require that the airguns be powered down or shut down if a turtle was sighted within the safety radius during airgun operations. Observations for sea turtles were also made during daytime periods from the *SJII* support vessel.

Visual Monitoring Methods

Monitoring methods for sea turtles were the same as those described in Chapters 3 and 4 for marine mammals.

Visual Monitoring Results

Sea Turtle Sightings

Two sea turtles were sighted from the *Ewing* during the SE Caribbean Sea cruise. A hawksbill turtle and an unidentified turtle were seen at distances of 10 and 20 m from the observers, respectively, during operations with the 20-airgun array (Table 5.1; Fig. 5.1). Power downs had to be implemented for both sightings because the turtles were sighted well within the safety radii. However, the single airgun operating during the power downs did not have to be shut down, as the turtles did not approach within the safety radius of one airgun (allowing for the offset between the observers and the airgun).

Two sightings of single turtles were made from the *SJII*. An unidentified turtle (possibly a green turtle) was seen, as well as a leatherback turtle (Table 5.1; Fig. 5.1). No mitigation actions were required as the *SJII* did not operate airguns.

No other vessels were seen during the sea turtle sightings.

Behavior

Behavioral data were collected for all four sea turtle sightings (Table 5.1). The two turtles observed from the *Ewing* were seen while the full 20-airgun array was firing. The unidentified turtle (possibly a leatherback or green turtle) was first seen off the starboard side ~20 m from ship. It swam vigorously underwater, away from the airgun array. The hawksbill turtle was first seen ~10 m from the vessel. It was then seen swimming away from the vessel at a vigorous pace. The observed behaviors of these two turtles could have been in response to the seismic sounds, or possibly the physical presence of the vessel. The unidentified sea turtle seen from the *SJII* was initially seen swimming, but it then dove as the vessel approached. Similarly, the leatherback turtle was initially seen resting at the surface, and it too dove as the vessel approached.

Summary and Conclusions

The small number of sea turtle sightings from the *Ewing* (n = 2) and the *SJII* (n = 2) limits interpretation of behavior relative to seismic operations and also limits comparisons between seismic and no-seismic periods. However, both turtles seen from the Ewing swam away vigorously; this behavior could have been in response to the operating airguns or the mere physical presence of the vessel. The two sea turtles seen from the *SJII* responded by diving as the vessel approached the animals. Per the IHA, the airguns were powered down when the turtles were sighted within the safety radius of the 20-gun array. However, the airguns did not have to be shut down, as the turtles did not approach within the safety radius of one airgun.

TABLE 5.1. Summary of sea turtle sightings from the *Ewing* and *SJII* during the SE Caribbean cruise, 18 April – 3 June 2004.

Species	Group Size	Date 2004	Time GMT	Lat. (ºN)	Long. (ºW)	CPA[1] (m)	Seismic Activity (No. of Guns)	Water Depth (m)	Mitigation	Initial Behavior / Second Behavior	Additional Information
Sightings from											
Unidentified turtle	1	9 May	16:56	13.7145	67.6653	20	Ramp up (Unknown)	5086	Guns were powered down	Swimming	Possibly leatherback or green turtle; turtle was seen swimming away vigorously underwater.
Hawksbill turtle	1	11 May	18:56	12.22.95	66.6300	10	On (20)	952	Guns were powered down	Swimming	Seen swimming away from the vessel underwater at a vigorous pace.
Sightings from SJII											
Unidentified turtle	1	20 April	20:08	14.9372	69.6740	<1	N/A	>1000	N/A	Swimming/ Diving	Possible green turtle; seen by ship's mate during transit to study area.
Leatherback turtle	1	15 May	15:24	11.3072	64.6377	2	N/A	>100	N/A	Resting/ Diving	Turtle was first seen resting at the surface, but as ship approached, it dove. Turtle seen while vessel was traveling.

Note: N/A means not applicable.
[1] CPA = closest observed point of approach to the vessel.

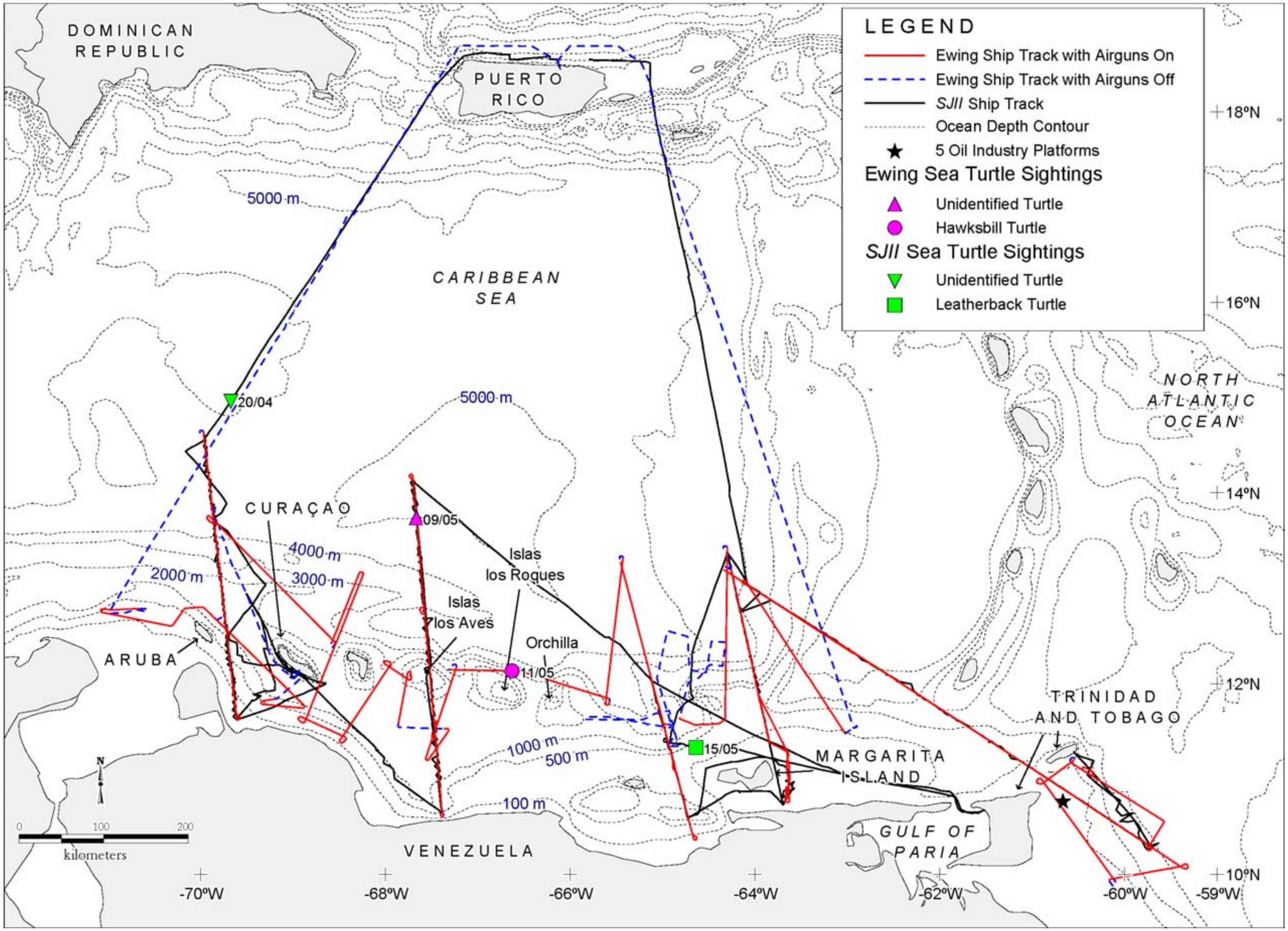

FIGURE 5.1. Sea turtle sightings from the *Maurice Ewing* (*Ewing*) and *Seward Johnson II (SJII)* during the SE Caribbean seismic study.

6. ACKNOWLEDGEMENTS

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The crew on the seismic source vessel R/V *Maurice Ewing* was extremely supportive of the marine mammal monitoring and mitigation effort. In particular, we acknowledge the assistance of Captain Mark C. Landow, Stanley Zeigler (Chief Mate), Rick Thomas (Second Mate), Shankar Bhardwaj, (Third Mate), Ted Koczynski (Science Officer and Technician), John Collins (Science Officer), and Richard Oliver-Goodwin (Computer Technician).

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The vessel-based fieldwork was made possible by the dedicated participation of marine mammal observers Joseph Beland, Howie Goldstein, and Sarah Stoltz of L-DEO, Suzanne Yin, along with the lead marine mammal observer, Mari Smultea, and marine mammal observers Meike Holst and Steve MacLean of LGL. We also thank the Venezuelan observer Alejandro Sayegh, the Eastern Regional Coordinator of CIC, and marine mammal bioacoustician Claudio Fossati of CIBRA, University of Pavia, Italy, for their dedicated field assistance and their expertise.

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8. APPENDICES

APPENDIX A:
Incidental Harassment Authorization Issued to L-DEO for the Seismic Study in the Southeast Caribbean Sea and Adjacent Atlantic Ocean[4]

DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE

Incidental Harassment Authorization

Lamont-Doherty Earth Observatory, Columbia University, P.O. Box 1000, 61 Route 9W, Palisades, New York 10964-8000, is hereby authorized under section 101(a)(5)(D) of the Marine Mammal Protection Act (16 U.S.C. 1371 (a)(5)(D) and 50 CFR 216.107, to harass small numbers of marine mammals incidental to conducting a marine seismic survey program in the Southeast Caribbean Sea and adjacent Atlantic Ocean, off the coast of Venezuela, contingent upon the following conditions:

1. The Authorization is valid from April 16, 2004 through April 15, 2005.

2. This Authorization is valid only for activities associated with conducting a seismic survey program in the Southeast Caribbean Sea and adjacent Atlantic Ocean, off the coast of Venezuela from the *R/V Maurice Ewing* and the *R/V Seaward Johnson*.

3. (a) The taking, by incidental harassment only, is limited to the species listed under condition 3(b) below. The taking by serious injury or death of these species or the taking by harassment, injury or death of any other species of marine mammal is prohibited and may result in the modification, suspension or revocation of this Authorization.

(b) The species authorized for incidental harassment takings are: the sperm whale (Physeter macrocephalus), pygmy sperm whale (Kogia breviceps), dwarf sperm whale (Kogia sima), Cuvier's beaked whale (Ziphius cavirostris), Gervais' beaked whale (Mesoplodon europaeus), Blainville's beaked whale (Mesoplodon densirostris), rough-toothed dolphin (Steno bredanensis), tucuxi (Sotalia [fl]uviatilis), bottlenose dolphin (Tursiops truncatus), pantropical spotted dolphin (Stenella attenuata), Atlantic spotted dolphin (Stenella frontalis), spinner dolphin (Stenella longirostris), clymene dolphin (Stenella clymene), striped dolphin (Stenella coeruleoalba), long-beaked common dolphin (Delphinus capensis), Fraser's dolphin (Lagenodelphis hosei), Risso's dolphin (Grampus griseus), melon-headed whale (Peponocephala electra), pygmy killer whale (Feresa attenuata), false killer whale (Pseudorca crassidens), killer whale (Orcinus orca), short-finned pilot whale (Globicephala macrorhynchus), humpback whale (Megaptera novaeangliae), minke whale (Balaenoptera acutorostrata), Bryde's whale

[1] This is a verbatim copy (retyped) of the IHA. However, some amendments/additions were made to this IHA after it was noted that the IHA was inconsistent with the *Federal Register* notice (NMFS 2004). When the amendments/additions were made (14 May 2004), the seismic survey had already commenced. The amendments are indicated by footnotes in this IHA, and the additional monitoring and mitigation measures are listed at the end of this IHA.

(Balaenoptera edeni), sei whale (Balaenoptera borealis), fin whale (Balaenoptera physalus), and blue whale (Balaenoptera musculus).

(c) The authorization for taking by harassment is limited to the following acoustic sources without an amendment to this Authorization:

(1) A seismic airgun array with no more than 20 airguns operating;
(2) A multi-beam bathymetric sonar; and
(3) A sub-bottom profiler

(d) The taking of any marine mammal in a manner prohibited under this Authorization must be reported within 48 hours of the taking to the Chief of the Marine Mammal Conservation Division, Office of Protected Resources, National Marine Fisheries Service, at (301) 713-2322, ext 101.

4. The holder of this Authorization is required to cooperate with the National Marine Fisheries Service and any other Federal, state or local agency monitoring the impacts of the activity on marine mammals. The holder must notify the Chief of the Marine Mammal Conservation Division at least 48 hours prior to starting the seismic survey (unless constrained by the date of issuance of this Authorization in which case notification shall be made as soon as possible).

5. Mitigation. The holder of this authorization is required to:

(a) Establish and monitor the marine mammal safety zones at the 180 dB (re 1 μPa_{rms}) isopleth that is based upon calibration measurements made for the airgun array in the Caribbean Sea and Atlantic Ocean. The radii around the 20-airgun array are established at 900 m (2953 ft) for water depths greater than 1000 m (3281 ft). For water depths between 100 and 1000 m (328 and 3281 ft), the safety radius is 1350 m (4429 ft). For water depths less than 100 m (328 ft), the safety radius is 3500 m (11483 ft) for 180 dB.

(b) Immediately power-down the seismic airgun array and/or other acoustic sources, whenever any marine mammals are sighted approaching close to or within the area delineated by the 180 dB (re 1 μPa_{rms}) isopleth as established under condition 5(a) for the authorized seismic sources.

(c) Not proceed with powering up the seismic airgun array unless the safety zone described in condition 5(a) is visible and no marine mammals or sea turtles are detected within the appropriate safety zones; or until 15 minutes (for small odontocetes and pinnipeds) or a minimum of 30 minutes (for mysticetes/large odontocetes) after there has been no further visual detection of the animal(s) within the safety zone and the trained marine mammal observer on duty is confident that no marine mammals or sea turtles remain within the appropriate safety zone.

(d) Prior to commencing ramp-up described in condition 5(h), conduct a 30-minute period of observation by at least one trained marine mammal observer (1) at the commencement of seismic operations and (2) at any time electrical power to the airgun array is discontinued for a period of 1 hour or more.

(e) Use the SEAMAP Passive Acoustic Monitoring System to monitor for vocalizing marine mammals and to notify visual observers of nearby marine mammals whenever water depths permit.

(f) If the complete safety radii are not visible for at least 30 minutes prior to ramp-up in either daylight or nighttime, not commence ramp-up unless the seismic source has maintained an SPL of at least 180 dB during the interruption of seismic survey operations.

(g) If no marine mammals have been observed while undertaking mitigation condition 5(c), 5(d) and 5 (e), ramp-up airgun arrays at a rate no greater than 6 dB per 5-minutes until operating levels are reached: (1) At the commencement of seismic operations, and (2) anytime after the array has been powered down for more than 2 minutes when the vessel speed is 4 knots or greater and 3 minutes when the vessel speed is less than 4 knots, by commencing with the smallest airgun first and then adding additional guns in sequence, until the full array is firing.[2]

(h) Airguns will not start up at night after a shutdown.

(i) To the extent practical, whenever a marine mammal is detected outside the safety radius, and based on its position and motion relative to the ship track is likely to enter the safety radius, an alternative ship speed or track will be calculated and implemented.

(j) Emergency shut-down. If observations are made or credible reports are received that one or more marine mammals of any species are within the area of this activity in an injured or mortal state, or are indicating acute distress, the seismic airgun array will be immediately shut down and the Chief of the Marine Mammal Conservation Division or a staff member contacted.

6. Monitoring

(a) The holder of this Authorization must designate at least three biologically-trained, on site individuals to be onboard the *Maurice Ewing* and two to three individuals to be onboard the *Seward Johnson*, approved in advance by the National Marine Fisheries Service, to conduct the visual monitoring and at least two trained individual to conduct passive acoustic monitoring under this Authorization and to record the effects of seismic surveys and the resulting noise on marine mammals and sea turtles.

(b) Monitoring is to be conducted by the biological observers described in condition 6(a) above, onboard the active seismic vessels. The observers must be on active watch whenever the seismic array is operating during all daylight hours and, where possible, two observers whenever either of the seismic arrays are being powered up to (a) ensure that no marine mammals enter the appropriate safety zone whenever the seismic array is on, and (b) to record marine mammal and sea turtle activity as described in condition 6(f) below.

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[2] Mitigation 5(g)(2) is incorrect. Per e-mail from Kimberly Skrupky of NMFS on 4 May 2004, repeated in NMFS (2004, p. 24582, col. 3), it should say “At 4 knots, the source vessel would travel 900 m (2953 ft) during an 8-minute period. If the towing speed is reduced to 3 knots or less, as sometimes required when maneuvering in shallow water, ramp-up will be required after a "no shooting" period lasting 10 minutes or longer. At towing speeds not exceeding 3 knots, the source vessel would travel no more than 900 m (3117 ft) in 10 minutes.”

(c) To the extent possible, observers will be on watch for continuous periods of 4 hours or less.

(d) At all times, the crew must be instructed to keep watch for marine mammals and sea turtles. If any are sighted, the bridge watch-stander must immediately notify the biological observer, who is on standby during night-time operations. If a marine mammal or sea turtle is within, or closely approaching, its designated safety zone, the source must be immediately powered down.

(e) Observations, by the biological observers described in condition 6(a) above, on marine mammal presence and activity will begin a minimum of 30 minutes prior to the estimated time that the seismic source(s) are to be turned on and/or ramped-up.

(f) Monitoring will consist of noting (1) the species, group size, age/size/sex categories (if determinable), the general behavioral activity, heading (if consistent), bearing and distance from seismic vessel, sighting cue, and apparent reaction of all marine mammals and sea turtles seen to the seismic vessel and/or its airgun array (e.g., none, avoidance, approach, paralleling, etc) and behavioral pace; (2) the time, location, heading, speed, and activity of the vessel (shooting or not), along with sea state, visibility, cloud cover and sun glare at (i) any time a marine mammal or sea turtle is sighted, (ii) at the start and end of each watch, and (iii) during a watch (whenever there is a change in one or more variable); and, (3) the identification of all vessels that are visible within 5 km of the seismic vessel whenever a marine mammal is sighted, and the time, bearing, distance, heading, speed and activity of the other vessel(s).

(g) All biological observers must be provided with and use appropriate night-vision devices, Big Eyes, and reticulated and/or laser range finding binoculars.

7. Reporting

(a) A draft report will be submitted to the National Marine Fisheries Service within 90 days after the end of the acoustic measurement program in the Caribbean Sea and the Atlantic Ocean. The report will describe in detail (1) the operations that were conducted, (2) the marine mammals and sea turtles that were detected near the operations, (3) to the extent possible the results of the acoustical measurements to verify the safety radii, and (4) the methods, results, and interpretation pertaining to all monitoring tasks, a summary of the dates and locations of seismic operations, sound measurement data, marine mammal and sea turtle sightings (dates, times, locations, activities, associated seismic survey activities), and estimates of the amount and nature of potential take of marine mammals by harassment or in other ways.

(b) The 90-day draft report will be subject to review and comment by the National Marine Fisheries Service. Any recommendations made by the National Marine Fisheries Service must be addressed in the final report prior to acceptance by the National Marine Fisheries Service. The draft report will be considered the final report for this activity under this Authorization if the National Marine Fisheries Service has not provided comments and recommendations within 90 days of receipt of the draft report.

8. Activities related to the monitoring described in this Authorization do not require a separate scientific research permit issued under section 104 of the Marine Mammal Protection Act.

9. A copy of this Authorization must be in the possession of the operator of the vessel operating under the authority of this Incidental Harassment Authorization.

Additional Monitoring and Mitigation Measures Included in the *Federal Register* Notice[3]

1. "…LDEO will not initiate a ramp-up at night from a power down of an airgun array involving greater than 6 guns if the *Ewing* is operating in shallow water (≤100 m (328 ft)). In that situation, the safety radius would extend too large from the ship to effectively monitor visually at night." (NMFS 2004, p. 24576, col. 2)

2. "…However, LDEO can initiate ramp-up from a power-down situation when operating in water deeper than 100 m (328 ft) at night if the 180-dB radius is either visible or the passive sonar has not recorded any mammalian vocalizations during the entire period of the power-down." (NMFS 2004, p. 24576, col. 2)

3. "…If marine mammals are detected during daylight hours, the passive acoustic monitoring will need to continue to be operated throughout the succeeding night." (NMFS 2004, p. 24578, col. 3)

4. "…Ramp-up [during the day] may not begin unless the entire 180-dB safety radius is visible (i.e., no ramp-up can begin in heavy fog or high sea states)." (NMFS 2004, p. 24579, col. 2)

5. "…LDEO will conduct post-survey monitoring by sub-sampling for marine mammals along the *Ewing*'s MCS/OBS seismic lines by the R/V *Seward Johnson's* conducting observations for marine mammals along various sections of the seismic lines. … Post-survey monitoring will be achieved by observer effort along each of the profiles prior to, during, and following the seismic activity. This will provide the biological observers with several opportunities to determine marine mammal distribution and abundance along the transit lane, conduct observational and acoustical monitoring and look for injured or dead marine mammals." (NMFS 2004, p. 24580, col. 3)

APPENDIX B:
L-DEO Memo Regarding Whale Carcass

To: File

From: G.M. Purdy, Director, Lamont-Doherty Earth Observatory (LDEO) of Columbia University

Subject: *Ewing* Operations May 15th-17th 2004

Date: May 18th, 2004

On 15 May 2004 at about 10 AM local time in a position off the northern coast of Venezuela, approximately 43 nautical miles (nm) north west of Isla de Margerita and approximately 40 nm north east of Isla La Tortuga, the carcass of a whale was sighted by the marine mammal observers (MMO) on the R/V *Seward Johnson II*. The R/V *Seward Johnson II* is supporting the R/V *Maurice Ewing* SE Caribbean multi channel seismic program with the deployment and recovery of ocean bottom seismometers. Although the *Seward Johnson* was not shooting airguns, the National Marine Fisheries Service (NMFS) requested that in addition to the observers to be assigned to the *Ewing*, two MMOs be assigned to this ship to assist in marine mammal observations.

Upon receipt of this notification seismic operations on board *Ewing* were powered down and subsequently shut down, following standard procedures. At the time of this sighting the *Ewing* was approximately 25 miles to the east-south-east of the carcass location.

Over the next day analysis of the situation followed including:

• Review of *Ewing* track lines for the past five days indicated that the *Ewing* surveys advanced from west to east along the Venezuelan coast.

• Review of the set and drift by the currents that the whale carcass would have experienced based on known ocean currents. In this area the currents generally set to the west at a speed of ~1+ nautical miles per hour.

• Type of whale was identified as a Bryde's whale common to these waters.[5]

• Expertise of the MMO's was called upon to assess the condition of the carcass; throat pleats visible, bloated body, fin and tail stocks mostly eaten, and pieces of body tissue floating in water, and body color was light yellow or tan. Death was estimated at 4-6 days prior to the sighting of the carcass, by Alejandro Sayegh the Regional Coordinator of the Venezuelan Cetaceans Research Center.

[5] The whale was later positively identified from a high-resolution photograph as a fin whale by Alejandro Sayegh (CIC, Venezuela).

• At the time of the mammal's death the *Ewing*'s closest point of approach to the mammal is estimated at 123 nm. If the mammal had died earlier the closest point of approach based upon the *Ewing* track and an average computation of the currents, could increase to 230 or 280 nm.

• Given the state of the carcass decomposition (Condition Code 4), there was no observable indication of unnatural death from ship strike or from entanglement.

• Marine mammals of this species are known to regularly strand along the coast of Venezuela at this time of year.

The reports from the Captain and the MMO's, *Ewing* track charts, and photographs of the carcass were submitted to the National Marine Fisheries Service (NMFS) and several marine mammal experts. Their opinion on any possible relationship of this event with the *Ewing*'s seismic operations was requested. Excerpts from the responses are as follows:

Ken Hollingshead, Fishery Biologist, NMFS "…Field identification indicated that the dead whale was a Bryde's whale and it had been dead for approximately 4-5 days (Code 4 condition). Based on the currents in that region, the closest approach to the *Ewing* (3 days earlier) had been estimated to have been 123 nm, while its likely position 4 and 5 days earlier would have been 230 and 281 nm from the whale respectively. We have reviewed the situation of the dead Bryde's whale and the R/V *Maurice Ewing* and have determined that it is unlikely that the acoustic sounds from the *Ewing*'s scientific instruments was responsible for the whale's demise. NOAA Fisheries therefore approves of Lamont Doherty Earth Observatory resuming its scientific seismic research on the *Ewing*."

Dr. Peter Tyack, Woods Hole Oceanographic Institution

"I have reviewed the documents and agree with the MMO's that if the whale died 5+ days before it was sighted and could not have been closer than 123 n miles from the *Ewing* at the time, there could not be any relationship between the whale's death and *Ewing* activities. I am a behavioral ecologist, not a pathologist, but I do know that commercial seismic surveys routinely operate within tens of nautical miles from baleen whales, and I am not aware of any association with injury or death at ranges of tens of nautical miles. Given the size of many marine mammal populations, if you have excellent observers on board, you are likely to see animals that have died of natural causes."

John Richardson, Senior Vice President, LGL Ltd. Environmental Research Associates

"I've looked through the various messages re the dead whale, Mari's report, Alejandro's report, and the track maps. It seems quite obvious that the *Ewing* was far away when the whale must have died, and any cause-and-effect relationship is implausible in the extreme."

Dr. Roger Gentry, NOAA Fisheries Acoustics Program

"We know that the coast of Venezuela has quite a few strandings, so it came as no surprise to me that you encountered one during your work. I think your decision to suspend operations while considering whether the whale may have died as a result of your activities was responsible and prudent. When I compared the track of your vessel over 8 days with the likely location of the animal at death, and the condition of the carcass when it was found, it seemed to me that your conclusion that seismic sounds could not have caused this death was fully justified….”

Alejandro Sayegh, MMO. R/V Maurice Ewing. SE Caribbean Cruise, 2004, Regional Coordinator CIC (Cetaceans Research Center) Venezuela.

"………. the last year there were a total of 4 strandings of this species on Margarita Island's beaches.

Considering the stranding events, the reports from vessel's crew and the approximate distance between the R/V *Maurice Ewing* and where the individual was located at its moment of death, there is no reason to think that the seismic operations of the R/V *Maurice Ewing* in the SE Caribbean, between April 18th and the event's day (May 15th), could lead neither to the injury of this whale nor to its death."

Determination:

Based on the review by National Marine Fisheries Service and opinions expressed by four marine mammal experts the judgment was made by LDEO leadership that there is no plausible basis by which the marine mammal’s demise is attributable to *Ewing* operations. Therefore *Ewing* was authorized to resume seismic operations at 3:50 PM on 17 May 2004.

APPENDIX C:
Data Recorded during Marine Mammal and Sea Turtle Observations

The following are descriptions of data recorded for each marine mammal or sea turtle sighting during the late April – early June Caribbean seismic survey.

"Sighting Cue" was the feature that initially drew the observer's attention to the animal. Cues included head or body visible above the water's surface, or a splash resulting from a dive.

Several standardized behavior categories were used. "Behavior 1" was the behavior of the animal when initially sighted; "Behavior 2" was any subsequently observed behavior. Behaviors used for individual animals are identified and defined below:

- Sink — When a whale backs straight down under the water, hind flippers first, with an upright posture.
- Front Dive — A head-first dive.
- Thrash — A particularly "frantic" or "violent" dive.
- Fluking — When a cetacean brings its tail out of the water, followed by a front dive.
- Logging — A marine mammal or turtle resting at the surface.
- Spyhop — A cetacean raising its head vertically out of the water so its eyes clear the surface.
- Swim — A marine mammal moving along the surface, not underwater.
- Breach — A cetacean leaping or jumping clear of the water.
- Lobtail — A cetacean slapping the water with its flukes, sometimes repeatedly.
- Flipper slap — A large cetacean striking the foreflippers against the water.
- Feeding — Gathering food. Often evidenced by feeding birds or fish leaping out of the water.
- Blow — An exhalation at the surface. Visible as a cloud of moist air.
- Bow Riding — Small cetaceans traveling immediately in front of the source vessel, with assisted locomotion provided by the pressure wave.
- Porpoising — Small cetaceans or seals making low, arcing leaps as they travel rapidly near the surface.
- Rafting — Marine mammals not swimming, but more or less motionless on the surface, in a horizontal position.
- Wake Riding — Swimming in the waves or turbulence behind a moving vessel; includes turbulence associated with the airguns.
- Other — Not any of the above, described with a written comment.

For groups of marine mammals, the following behavioral states were used:

- Travel — The majority of individuals swimming steadily in the same direction. No surface activity.

- Surface Active Behaviors that create splashes, described with a written comment.
- Surface Travel Individuals in the group are surface active (as described above) while moving steadily in the same overall direction.
- Milling The majority of individuals in a group are moving or oriented in varying directions, but remaining in the same general location. No surface active behaviors. May occur while feeding.
- Feeding Individuals milling, traveling, or surface active and direct or circumstantial evidence indicates the presence of prey.
- Resting The majority of individuals are generally logging (see definition above) at the surface, not swimming.

A subjective assessment was made of the rate (**Pace**) at which animals behaved. Behaviors that appeared to be slow and controlled were coded as sedate. Behaviors that appeared to be agitated or frantic were coded as vigorous. Behaviors that were neither sedate nor vigorous were coded as moderate. Behavioral "Pace" was used as a descriptor that may be related to the level of disturbance of specific marine mammals.

The animals' direction (**Heading**) and initial position relative to the vessel's bow (**Bearing**) were recorded as positions on a clock face, with the bow at 12, and the stern at 6, abeam starboard was 3, and abeam port was 9.

Radial Distance to marine mammal groups was estimated visually using 7 × 50 Fujinon binoculars with reticles engraved on one ocular lens. Because of the nature of the optical system in the binoculars, estimates were more precise for animals located closer to the vessel.

APPENDIX D:

Results of Ground-Truthing of Night Vision Devices Aboard the R/V Maurice Ewing *during the Southeast Caribbean Seismic Cruise 18 April–3 June 2004*

The IHA specifies that MMOs are required to observe for marine mammals and sea turtles during some nighttime periods, including during ramp up from one or more airguns, or when a marine mammal is sighted at night. During this cruise, nighttime observations were conducted for a total of 6 h (52 km) during ramp up of the airgun array. NVDs used for night observations consisted of the Night Quest NQ220 equipped with a 3x magnification lens. Because the effective sighting distance of these NVDs for observing at sea at night are mostly unknown, a third ground-truthing session was undertaken aboard the *Ewing* while conducting seismic studies in the SE Caribbean Sea. Results of the previous two ground-truthing sessions were reported in Smultea and Holst (2003) and Holst (2004).

NVD Ground-truthing Methods

Ground-truthing of the NVDs occurred on 30 May 2004 aboard the Ewing from 02:47–03:15 GMT (22:47–23:15 local time on 29 May). Environmental conditions consisted of Beaufort Force 3, ~80% cloud cover, and a wind speed of ~14 kt. The moonphase was 90%, and the moon had a 66º altitude; it was a semi-bright night with some moonlight. The moonrise time was at 19:17 GMT (15:17 pm local time).

A 140-m long line of rope was measured out at 10-m intervals. Six white, plastic, 1-gallon milk jugs (with dimensions of 25 cm × 15 cm × 15 cm) were spray-painted black to resemble the color of a dolphin (plain white jugs were used during the previous two ground-truthing sessions). Each jug was tied with a separate line onto the long rope at 10-m intervals, starting at the end of the line. The long line of rope was then let out from the stern during airgun operations (previous ground-truthing trials were performed during transit, when airguns were not operational), while the vessel was moving at a speed of 4 knots. Two observers searched for the milk jugs using NVDs from the aft of the "A" deck, located ~15 m forward of the stern. The observer eye height at that location was ~9 m.

Initially, all 140 m of rope were let out, so that the distances of the six jugs to the observers were 105, 115, 135, 145, 155 m. The number of milk jugs that each observer could see was then noted. Then, the long line of rope was pulled in by 20 m, and the observers searched for the milk jugs again. The rope was pulled in by 20 m for 3 more trials, until 60 m of rope were out, with jugs located at distances of 25, 35, 45, 55, 65, and 75 m from the observers. During each trial, the observers searched for the milk jugs.

The entire exercise, including getting the jugs and rope ready and searching for the jugs, took ~1 hr.

Results of NVD Ground-truthing

When 140 m of rope were out, observer 1 saw one jug (either at 105 or 115 m), and the splashes made by four other milk jugs. The second observer saw splashes created by five of the jugs, but no jugs. When 120 m of rope were out, the first observer saw the first three jugs (at 85, 95, and 105 m), and splashes created by the last three jugs at 115, 125, and 135 m. Observer 2 saw splashes created by five of the jugs. During the next trial, when jugs were located at 65, 75, 85, 95, 105, and 115 m from the observers, observer 1 saw the first two jugs and splashes created by the last four jugs. Observer 2 saw splashes created by six of the jugs. When 80 m of rope were out, the first observer saw the closest two jugs at 45 and 55 m, and splashes created by the last four jugs. The second observer saw splashes created by four jugs, but noted that the other splashes created by the other jugs were impossible to see in the white water created by the airguns. During the last trial, when jugs were located at 25, 35, 45, 55, 65, and 75 m from the observers, observer 1 saw the closest four jugs and splashes created by another jug. The first observer noted that there was a lot of white water from the guns, which made it impossible to see the splashes of the last jug. The second observer saw the three closest jugs and splashes created by another jug. Again, the observer noted that it was difficult to see splashes created by the other jugs because of the white water.

Summary and Conclusions

Based on results of this ground-truthing session with the Night Quest NQ220 NVD, both observers could see evidence of the jugs' presence (i.e., splashes) out to ~155 m. However, observer 1 was consistently able to see the actual jugs, whereas observer 2 only saw the splashes created by the jugs.

During ground-truthing tests during the Hess Deep cruise in July 2003, all three observers could quickly and easily see white milk jugs located ~65, 115, 165, and 215 m away in dark Beaufort Force 3 conditions; all three observers could barely see a milk jug located ~265 m away. Ground-truthing tests during the TAG seismic cruise in the mid-Atlantic Ocean in October–November 2003 were conducted during a bright night in Beaufort Force 4. During these tests, observers could sight a white milk jug at 65 m and 1 of 3 observers could see a jug at a distance of 150 m.

The results suggest that the effective sighting distance of the NVDs is at least 155 m, but that the amount of moonlight and Beaufort Force also play a factor in sightability. It appears that the sighting distance of the NVDs is less during moonlit nights with high sea states compared with dark nights when the sea is calmer. During dark, relatively calm nights, the effective sighting distance is at least 200 and up to ~250 m or more.

APPENDIX E: Conservation Status of Marine Mammals Occurring in the SE Caribbean Sea and Adjacent Atlantic Ocean

Species	U.S. ESA / MMPA[1]	IUCN[2]	CITES[3]	Heritage Status[4]
Odontocetes				
Sperm whale (*Physeter macrocephalus*)	Endangered*	Vulnerable	I	G3G4
Pygmy sperm whale (*Kogia breviceps*)	Not Listed*	N.A.	II	G4
Dwarf sperm whale (*Kogia sima*)	Not Listed	N.A.	II	G4
Cuvier's beaked whale (*Ziphius cavirostris*)	Not Listed*	Data Deficient	II	G4
Gervais' beaked whale (*Mesoplodon europaeus*)	Not Listed*	Data Deficient	II	G3
Blainville's beaked whale (*Mesoplodon densirostris*)	Not Listed*	Data Deficient	II	G4
Rough-toothed dolphin (*Steno bredanensis*)	Not Listed	Data Deficient	II	G4
Tucuxi (*Sotalia fluviatilis*)	N.A.	Data Deficient	I	G4
Bottlenose dolphin (*Tursiops truncatus*)	Not Listed[§]	Data Deficient	II	G5
Pantropical spotted dolphin (*Stenella attenuata*)	Not Listed	Lower Risk/Conservation Dependent	II	G5
Atlantic spotted dolphin (*Stenella frontalis*)	Not listed	Data Deficient	II	G5
Spinner dolphin (*Stenella longirostris*)	Not Listed	Lower Risk/ Conservation Dependent	II	G5
Clymene dolphin (*Stenella clymene*)	Not Listed	Data Deficient	II	G4
Striped dolphin (*Stenella coeruleoalba*)	Not Listed	Lower Risk/ Conservation Dependent	II	G5
Long-beaked common dolphin (*Delphinus capensis*)	Not Listed*	N.A.	II[+]	G4G5
Fraser's dolphin (*Lagenodelphis hosei*)	Not Listed	Data Deficient	II	G4
Risso's dolphin (*Grampus griseus*)	Not Listed	Data Deficient	II	G5
Melon-headed whale (*Peponocephala electra*)	Not Listed	N.A.	II	G4
Pygmy killer whale (*Feresa attenuata*)	Not Listed	Data Deficient	II	G4
False killer whale (*Pseudorca crassidens*)	Not Listed	N.A.	II	G4

Species	U.S. ESA / MMPA[1]	IUCN[2]	CITES[3]	Heritage Status[4]
Killer whale (*Orcinus orca*)	Not Listed	Lower Risk/ Conservation Dependent	II	G4G5
Short-finned pilot whale (*Globicephala macrorhynchus*)	Not Listed*	Lower Risk/ Conservation Dependent	II	G5
Mysticetes Humpback whale (*Megaptera novaeangliae*)	Endangered*	Vulnerable	I	G3
Minke whale (*Balaenoptera acutorostrata*)	Not Listed	Lower Risk/ Near Threatened	I	G5
Bryde's whale (*Balaenoptera edeni*)	Not Listed	Data Deficient	I	G4
Sei whale (*Balaenoptera borealis*)	Endangered*	Endangered	I	G3
Fin whale (*Balaenoptera physalus*)	Endangered*	Endangered	I	G3G4
Blue whale (*Balaenoptera musculus*)	Endangered*	Endangered	I	G3G4
Sirenian West Indian manatee (*Trichechus manatus manatus*)	Endangered*	Vulnerable	I	G2

N.A. = Species status was not assessed.
[1] Endangered Species Act (Waring et al. 2003); North Atlantic or Gulf of Mexico stocks considered.
[2] IUCN Red List of Threatened Species (2003).
[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2004).
[4] InfoNatura (2004).
*Stock considered as strategic under the Marine Mammal Protection Act.
[§] Only the coastal stock (not offshore) is considered strategic and depleted under the Marine Mammal Protection Act.
[+] Previously known as *D. delphis.*

APPENDIX F:

Observation Effort

APPENDIX F-1. Marine mammal visual observation effort from the *Ewing* and *SJII* within and in transit to and from the SE Caribbean and adjacent North Atlantic study area, 18 April – 3 June 2004, in **(A)** hours and **(B)** kilometers, subdivided by Beaufort Wind Force and number of airguns operating (*Ewing*) or vessel activity (*SJII*). All observations were during daytime except 6 h and 52 km of observations made during night-time ramp-ups with airguns on aboard the *Ewing*. "Airguns Off" includes 85 h and 1258 km of observation effort on the *Ewing* while in transit between San Juan, Puerto Rico, and the study area. No effort was conducted with 2–7 airguns or 11–15 airguns operating for a sustained period or during Beaufort Force 0.

Airgun Status or Vessel Activity	Beaufort Force								Total
	1	2	3	4	5	6	7	Unknown	
(A) *Ewing* Visual Effort (h)									
Airguns on	1	15	87	95	178	45	3	1	425
Ramp Up	0	1	2	3	7	0	0	0	13
1 Airgun On	0	1	4	3	5	0	0	0	12
8-10 Airguns On	0	0	0	0	5	0	0	0	5
16-20 Airguns On	1	13	81	89	160	45	3	1	395
Airguns Off	0	0	27	37	14	7	0	0	85
Total	**1**	**15**	**114**	**132**	**192**	**52**	**3**	**1**	**510**
(B) *Ewing* Visual Effort (km)									
Airguns on	10	135	799	787	1518	377	25	11	3662
Ramp Up	0	8	22	22	58	1	0	0	111
1 Airgun On	0	5	31	20	50	0	0	0	106
8-10 Airguns On	0	0	0	0	50	0	0	0	50
16-20 Airguns On	10	122	746	745	1361	377	25	0	3388
Airguns Off	0	0	336	606	213	107	0	0	1258[b]
Total	**10**	**135**	**1135**	**1393**	**1731**	**485**	**25**	**6**	**4920**
(A) *SJII* Visual Effort (h)									
Deploy/Retrieve OBSs	5	29	32	23	6	0	0	0	94
Underway in Study Area	22	70	68	81	15	2	0	0	257
Transit San Juan to/from Study Area	18	8	16	1	0	0	0	0	43
Total	**45**	**107**	**115**	**105**	**21**	**2**	**0**	**0**	**394**
(B) *SJII* Visual Effort (km)									
Deploy/Retrieve OBSs	78	162	123	128	19	0	0	0	510
Underway in Study Area	292	1075	1040	1150	180	26	0	0	3763
Transit San Juan to/from Study Area	332	146	323	10	1	0	0	0	813
Total	**703**	**1384**	**1485**	**1289**	**200**	**26**	**0**	**0**	**5087**

[a] Ramping up involved firing by 1–19 airguns of the 20-airgun array.

[b] Excludes 6 km undetermined effort.

APPENDIX F.2. Marine mammal visual observation effort from the *Ewing* within and in transit to and from the SE Caribbean study area, 18 April – 3 June 2004, in **(A)** hours and **(B)** kilometers, subdivided by seismic status and number of airguns operating. Observations were during daytime except 6 h and 52 km of nighttime ramp up observations with airguns on. "Airguns Off" includes 85 h and 1266 km of observation effort while in transit between San Juan, Puerto Rico, and the SE Caribbean study area. No effort was conducted with 2–7 airguns or 11–15 airguns operating for a sustained period.

Seismic Status or Vessel Activity	Number of Airguns On					
	0	**1**	**8-10**	**16-20**	**Ramp Up**	**Total**
(A) *Ewing* Visual Effort (h)						
Airguns On	0	12	6	395	13	425
Airguns Off						
Pre-seismic	19					19
Off 0-2 h	7					7
Off 2-6 h	8					8
Off >6 h	30					30
Post-seismic	21					21
Total Airguns Off	85					85
Total	**85**	**12**	**6**	**395**	**13**	**510**
(B) *Ewing* Visual Effort (km)						
Airguns On	0	106	50	3388	110	3662[a]
Airguns Off						
Pre-seismic	225					225
Off 0-2 h	66					66
Off 2-6 h	86					86
Off >6 h	410					410
Post-seismic	471					471
Total Airguns Off	1258					1258
Total	**1258**	**106**	**50**	**3388**	**110**	**4920**[a]

[a] Includes 8 km undetermined effort.

APPENDIX F.3. Marine mammal passive acoustic monitoring effort from the *Ewing* in the SE Caribbean and adjacent North Atlantic study area, 20 April–1 June 2004, in ***(A)*** hours and ***(B)*** kilometers, subdivided by night versus day and airgun activity. No passive acoustic monitoring was conducted during transit to and from San Juan outside the seismic survey area or from 15–17 May (see Table 2.2). No effort was conducted with 2–7 airguns or 11–15 airguns operating for a sustained period.

Seismic Status	Night	Day	Unknown	Total
***(A) Ewing* Acoustic Effort (h)**				
Airguns on	379	421	0	800
Ramp Up	3	10	0	13
1-6 Airguns On	8	11	0	19
8-10 Airguns On	9	7	0	16
16-20 Airguns On	360	392	0	752
Airguns Off	27	16	0	43
Unknown	7	5	0	12
Total	**406**	**437**	**3**	**846**[a]
***(B) Ewing* Acoustic Effort (km)**				
Airguns on	3142	3658	26	6826
Ramp Up	26	91	1	118
1-6 Airguns On	58	98	0	156
8-10 Airguns On	61	57	0	119
16-20 Airguns On	2941	3365	25	6333
Airguns Off	420	129	0	549
Unknown	53	41	0	95
Total	**3562**	**3787**	**26**	**7375**[a]

[a] Excludes 12 h or 95 km undetermined.

APPENDIX G: Summary of Visual and Acoustic Detections Made from the R/V Maurice Ewing *and R/V* Seward Johnson II *during the SE Caribbean Cruise, 18 April 18 – 3 June 2004*

Vessel	Acoustic and/or Visual[1]	SPECIES	Group Size	Date in 2004	Time (GMT)[2]	Latitude (°N)	Longitude (°W)	CPA[3] (m)	Initial Move-ment[4]	First Behav-ior[5]	Sea State[6]	Water depth[7] (m)	Vessel Activity[8]	# Guns On	Mitigation Measure[9]
Ewing	A	Sperm whale (possible id.)		21-Apr	22:13-22:28	12.6733	69.8595					1075	SH	20	NO
Ewing	A	Unid. dolphin		22-Apr	02:48-03:00	12.7068	69.7407					1300	SH	20	NO
Ewing	A	Unid. dolphin		22-Apr	09:21-09:50	13.2800	69.8095					3000	SH	20	NO
Ewing	A	Unid. dolphin		28-Apr	01:22-01:36	11.7588	69.3007					452	SH	1	NO
Ewing	A	Unid. dolphin		28-Apr	04:35-05:40	11.0310	69.0000					500	SH	1	NO
Ewing	A	Unid. dolphin		28-Apr	06:21-07:00	11.7298	68.9880					910	SH	1	NO
Ewing	A	Unid. dolphin		28-Apr	08:00-09:30	11.7233	68.8845					1050	SH	1-20	NO
Ewing	A	Unid. dolphin		28-Apr	11:37-12:08	11.9433	69.0848					1370	SH	20	NO
Ewing	A	Unid. dolphin		1-May	04:25-04:55	19.4518	69.9505					4300	SH	20	NO
Ewing	A	Unid. dolphin		1-May	14:36-15:02	14.1608	69.5720					4445	SH	20	NO
Ewing	A	Unid. dolphin		1-May	16:06-16:27	13.9570	69.8908					4528	SH	19-20	NO
Ewing	A	Unid. dolphin (possible Risso's dolphin)		1-May	17:46-17:51	13.8353	69.8762					4900	SH	20	NO
Ewing	A	Unid. dolphin		4-May	02:37-02:39	12.2118	68.6131					1560	SH	20	NO
Ewing	A	Unid. dolphin		6-May	02:10-02:59	11.5205	67.8387					1917	SH	12	NO
Ewing	A	Sperm whale		6-May	08:40-09:30	11.5036	67.4485					1930	SH	8	NO
Ewing	A	Sperm whale		6-May	11:38-12:34	11.4405	67.3467					1944	SH	8-10	NO
Ewing	A	Unid. dolphin		6-May	20:11-21:13	11.4927	67.4606					1936	SH	17-19	NO
Ewing	A	Unid. dolphin		6-May	23:56-00:54	11.4071	67.4585					1840	SH	20	NO
Ewing	A	Unid. dolphin		7-May	01:58-04:03	11.2433	67.4437					1802	SH	20	NO
Ewing	A	Unid. dolphin		7-May	06:05-06:15	11.9221	67.4136					950	SH	20	NO
Ewing	A	Unid. dolphin		7-May	19:58-20:56	11.3197	67.4504					1849	SH	20	NO
Ewing	A	Sperm whale		7-May	23:31-23:48	11.5933	67.4748					1782	SH	20	NO
Ewing	A	Unid. dolphin		8-May	00:21-00:22	11.6732	67.4818					1484	SH	20	NO
Ewing	A	Unid. dolphin		8-May	03:13	11.8879	67.5012					792	SH	20	NO
Ewing	A	Unid. dolphin		8-May	16:05-16:15	12.7280	67.5758					4432	SH	16	NO
Ewing	A	Unid. dolphin		11-May	01:30-02:16	11.6395	67.4097					1571	SH	20	NO
Ewing	A	Unid. dolphin		12-May	03:58-04:08	11.9332	65.9572					1046	SH	20	NO
Ewing	A	Sperm whale		12-May	11:45	11.8418	65.6082					3427	SH	17	NO
Ewing	A	Unid. dolphin		12-May	15:24-15:55	12.1187	65.5745					4046	SH	20	NO
Ewing	A	Unid. dolphin		13-May	00:46-00:51	12.8584	65.4833					4892	SH	20	NO
Ewing	A	Unid. dolphin		13-May	02:11-02:56	12.9693	65.4695					4670	SH	20	NO
Ewing	A	Unid. dolphin		13-May	08:20-08:30	13.1983	65.4408					4140	SH	20	NO
Ewing	A	Unid. dolphin		13-May	20:18-20:35	12.2877	65.1935					4003	SH	20	NO

Vessel	Acoustic and/or Visual[1]	SPECIES	Group Size	Date in 2004	Time (GMT)[2]	Latitude (N)	Longitude (W)	CPA[3] (m)	Initial Move-ment[4]	First Behav-ior[5]	Sea State[6]	Water depth[6] (m)	Vessel Activity[7]	# Guns On	Mitigation Measure[8]
Ewing	A	Unid. dolphin		14-May	07:29	11.4474	64.9637					2000	SH	20	NO
Ewing	A	Unid. dolphin		15-May	02:18-02:22	10.6212	64.7376					1015	SH	20	NO
Ewing	A	Unid. dolphin		15-May	08:06-08:12	11.0665	64.8705					131	SH	16	NO
Ewing	A	Unid. dolphin		15-May	09:20-09:30	11.1610	64.8862					300	SH	20	NO
Ewing	A	Unid. dolphin		16-May	00:35-00:55	11.6285	65.6300					1620	OFF	0	NO
Ewing	A	Unid. dolphin (possible bottlenose dolphin)		18-May	02:57-03:26	11.5515	64.5112					1280	SH	18	NO
Ewing	A	Unid. dolphin		18-May	08:59-09:19	11.8815	64.3202					147	SH	20	NO
Ewing	A	Unid. dolphin		18-May	19:09-19:17	12.7427	68.3082					3150	SH	20	NO
Ewing	A	Unid. dolphin		20-May	00:17-00:27	12.1433	64.0242					2600	SH	20	NO
Ewing	A	Unid. dolphin		20-May	03:15-06:54	11.9643	63.9833					327	SH	20	NO
Ewing	A	Unid. dolphin		20-May	08:18	11.5838	63.8963					269	SH	20	NO
Ewing	A	Unid. dolphin		22-May	04:59-06:00	13.0410	64.2293					3179	SH	20	NO
Ewing	A	Unid. dolphin		23-May	04:23-05:15	12.3200	62.9782					2957	SH	20	NO
Ewing	A	Unid. dolphin		23-May	06:48-07:35	12.2217	62.8065					2900	SH	20	NO
Ewing	A	Unid. dolphin		24-May	00:48-00:53	11.3425	61.6151					200	SH	19	NO
Ewing	A	Unid. dolphin		24-May	04:31-04:32	11.3615	61.4355					171	SH	20	NO
Ewing	A	Unid. dolphin		25-May	22:24-00:50	10.0182	59.6368					900	SH	17-20	NO
Ewing	A	Unid. dolphin		26-May	05:03-05:26	9.9210	60.1635					900	SH	17-20	NO
Ewing	A	Unid. dolphin (possible bottlenose dolphin)		27-May	08:05-09:08	11.1280	60.5470					82	SH	19-20	NO
Ewing	A	Unid. dolphin		28-May	03:44-04:04	10.5963	59.6703					1177	SH	20	NO
Ewing	A	Unid. dolphin		28-May	20:53-20:54	10.6776	60.3582					90	SH	20	NO
Ewing	A	Unid. dolphin		28-May	15:47-15:22	11.6450	61.8852					681	SH	20	NO
Ewing	A	Unid. dolphin		29-May	21:11-22:01	11.9050	62.2998					2282	SH	20	NO
Ewing	A	Unid. dolphin		30-May	03:16-04:45	12.1855	62.7483					2931	SH	20	NO
Ewing	A	Unid. dolphin		30-May	12:27-12:35	12.6378	63.4783					1022	SH	20	NO
Ewing	A	Unid. dolphin		30-May	13:48-14:18	12.7078	63.5918					1080	SH	20	NO
Ewing	A	Unid. dolphin		30-May	15:29-15:37	12.7957	63.7442					1834	SH	20	NO
Ewing	A	Unid. dolphin		30-May	18:52-18:59	12.9603	64.0000					2887	SH	20	NO
Ewing	A	Unid. dolphin		30-May	22:51-23:31	12.9598	64.0438					2952	SH	20	NO
Ewing	A	Unid. dolphin		31-May	05:41-09:13	12.5783	63.7815					2368	SH	20	NO
Ewing	A	Unid. dolphin		31-May	13:38	12.1483	63.4915					2222	SH	20	NO
Ewing	A	Unid. dolphin		31-May	22:02-00:07	11.7410	63.2167					728	SH	20	NO
Ewing	A	Unid. dolphin		1-Jun	04:34-05:03	11.4588	63.0265					73	ST	11-20	NO
Ewing	A*/V	Striped dolphin (probable id.)	7	20-Apr	21:09-02:30 (21:33-22:07)	12.7575	70.7884	2160	UN	BR	5	98	SH	1	NO
Ewing	A*/V	Unid. dolphin	35	4-May	11:10-11:30 (11:12-11:13)	11.6057	68.8608	1791	SA	SW	3	280	SH	20	NO

Vessel	Acoustic and/or Visual[1]	SPECIES	Group Size	Date in 2004	Time (GMT)[2]	Latitude (N)	Longitude (W)	CPA[3] (m)	Initial Move-ment[4]	First Behav-ior[5]	Sea State[6]	Water depth[6] (m)	Vessel Activity[7]	# Guns On	Mitigation Measure[8]
Ewing	A*/V	Sperm whale	2	5-May	20:05-20:40 (20:17-20:22)	11.9667	67.7667	1258	UN	TR	5	1110	SH	20	NO
Ewing	A/V*	Pantropical spotted dolphin	30	8-May	13:41-13:46 (13:41-13:44)	12.7211	67.5760	20	SP	TR	5	4462	SH	20	PD&SD
Ewing	A*/V	Sperm whale	6	11-May	17:55-19:25 (17:55-18:32)	12.1111	66.7115	1258	NO	BL	5	709	SH	20	PD
Ewing	A/V*	Unid. dolphin (possible bottlenose dolphin)	3	14-May	10:30-10:54 (10:23-10:53)	11.2372	64.9060	2729	ST	PO	2	760	SH	20	NO
Ewing	A/V*	Atlantic spotted dolphin	55	14-May	11:50-12:10 (11:46-12:22)	11.1303	64.8768	176	UN	FE	2	150	SH	20	PD
Ewing	A/V*	Long-beaked common dolphin	50	14-May	18:15-18:17 (17:45-19:55)	10.6692	64.7508	1017	SP	TR	2	951	SH	20	PD
Ewing	A*/V	Sperm whale	3	18-May	13:34-14:22 (13:47-14:10)	12.2758	64.3148	1337	SP	RE	3	3670	SH	20	NO
Ewing	A/V*	Bottlenose dolphin (probable id.)	20	19-May	11:46-11:51 (11:45-11:56)	12.9184	64.2011	15	ST	ST	4	3119	SH	20	PD
Ewing	A/V*	Spinner dolphin	80	21-May	11:46-12:12 (11:32-12:17)	11.6162	63.8307	20	ST	TR	3	360	SH	20	PD&SD
Ewing	A*/V	Sperm whale	1	23-May	11:48-12:06 (12:03-12:15)	12.0004	62.4524	654	SA	BL	4	1800	SH	20	PD
Ewing	V	Unid. whale	2	20-Apr	17:23	12.7417	70.6468	3300	UN	BL	6	100	TRANSIT	0	NO
Ewing	V	Unid. turtle	1	9-May	16:56	13.7145	67.6653	20	SA	SW	5	5086	SH	20	PD
Ewing	V	Hawksbill turtle	1	11-May	18:56	12.1096	66.6300	10	SA	SA	5	952	SH	20	PD
Ewing	V	Unid. whale	2	14-May	20:51	10.4262	64.6843	1500	UN	BL	3	476	SH	20	NO
Ewing	V	Unid. Dolphin[10]	15	17-May	09:47	12.2779	64.7190	20	ST	TR		>1000	OFF	0	NO
Ewing	V	Unid. Dolphin (possible bottlenose dolphin)	4	17-May	11:19-11:21	12.2780	64.7190	100	MI	FE	4	3828	OFF	0	NO
Ewing	V	Unid. whale	2	19-May	09:50-10:00	13.0317	64.2270	900	SA	TR	4	900	SH	20	PD
Ewing	V	Bryde's whale[11]	1	20-May	12:12	11.3265	63.7725	1958	SA	BL	3	35	SH	20	PD
Ewing	V	Bryde's whale	2	21-May	11:14-11:47	11.5797	63.8160	1958	SP	TR	3	147	SH	20	NO
Ewing	V	Unid. baleen whale (possible Bryde's whale)	1	21-May	12:20-12:21	11.6708	63.8640	2074	UN	BL	3	500	OFF	0	NO
Ewing	V	Unid. whale	1	22-May	22:40	12.5643	63.4683	4633	UN	BL	2	1249	SH	19	NO
Ewing	V	Striped dolphin	60	1-Jun	12:28-12:29	11.8258	63.0392	50	ST	PO	4	1125	TRANSIT	0	NO
SJII	V	Unid. turtle[12]	1	20-Apr	20:08	14.9372	69.6740	<1	MI	SW	1	>1000	TRANSIT	N/A	NO
SJII	V	Long-beaked common dolphin	9	21-Apr	12:31-12:38	13.3973	69.8233	<1	ST	PO	2	3285	TR	N/A	NO
SJII	V	Long-beaked common dolphin	15	22-Apr	15:02-15:17	11.8783	69.3765	5	ST	PO	1	>100	TR	N/A	NO
SJII	V	Unid. dolphin	1	22-Apr	17:41	11.9047	69.2225	<1	SA	DI	1	>1000	TR	N/A	NO
SJII	V	Unid. dolphin	5	22-Apr	18:54	12.0270	69.2107	10	SP	PO	1	>1000	TR	N/A	NO
SJII	V	Atlantic spotted dolphin	15	30-Apr	21:52	11.8655	69.6488	4	SA	SW	5	>100	OS	N/A	NO
SJII	V	Unid. dolphin	1	30-Apr	19:23	11.7053	69.6540	3	ST	SW	5	N/A	TR	N/A	NO
SJII	V	Long-beaked common dolphin	20	3-May	21:37	13.4408	69.8192	5	SP	BR	4	>1000	TR	N/A	NO

Vessel	Acoustic and/or Visual [1]	SPECIES	Group Size	Date in 2004	Time (GMT)[2]	Latitude (N)	Longitude (W)	CPA[3] (m)	Initial Move-ment[4]	First Behav-ior[5]	Sea State[6]	Water depth[6] (m)	Vessel Activity[7]	# Guns On	Mitigation Measure[8]
SJII	V	Short-finned pilot whale (possible id.)	6	3-May	15:42	13.6045	69.8510	10	SP	SW	5	>1000	TR	N/A	NO
SJII	V	Short-finned pilot whale (probable id.)	3	9-May	11:29	11.0522	67.4295	5	SA	SW	3	>100	TR	N/A	NO
SJII	V	Unid. whale	1	13-May	20:01	10.7623	63.7460	1000	SP	SW	3	>100	TR	N/A	NO
SJII	V	Bottlenose dolphin	8	15-May	21:07	11.1312	63.5357	10	ST	PO	2	>100	TR	N/A	NO
SJII	V	Fin whale (dead/floating)	1	15-May	13:59	11.3423	64.8237	N/A	N/A	N/A	3	N/A	TR	N/A	PD&SD
SJII	V	Bottlenose dolphin	4	19-May	17:52	11.3188	64.9383	654	ST	PO	4	>1000	TR	N/A	NO
SJII	V	Long-beaked common dolphin	600	19-May	22:12	10.8093	64.7895	588	SP	PO	2	>100	OS	N/A	NO
SJII	V	Unid. Whale (possibly Bryde's whale)	1	19-May	22:00	10.8093	64.7895	533	SA	BL	2	>100	OS	N/A	NO
SJII	V	Bottlenose dolphin	10	20-May	15:47	11.0910	63.6597	400	ST	SW	2	>100	OS	N/A	NO
SJII	V	Unid. Whale (probable Bryde's whale)	1	20-May	14:58	11.1358	63.7507	700	SP	BL	2	>100	OS	N/A	NO
SJII	V	Atlantic spotted dolphin	80	21-May	19:09-19-30	11.5477	63.8887	5	ST	PO	3	>100	TR&OS	N/A	NO
SJII	V	Short-finned pilot whale	8	21-May	21:17-21:22	11.6887	63.9185	654	SP	SW	3	>100	TR	N/A	NO
SJII	V	Atlantic spotted dolphin	60	24-May	16:06-16:19	11.3573	61.4252	15	SP	PO	4	160	TR	N/A	NO
SJII	V	Atlantic spotted dolphin	8	25-May	18:21	11.2090	60.5003	150	ST	PO	4	>100	TR	N/A	NO
SJII	V	Bottlenose dolphin	5	25-May	17:44-17:53	11.1232	60.4162	1	ST	PO	4	>100	TR	N/A	NO
SJII	V	Unid. dolphin[13]	11	28-May	16:37-16:40	10.7778	60.0887	100	ST	SW	4	>100	TR	N/A	NO
SJII	V	Long-beaked common dolphin	40	30-May	10:20	11.7482	62.0502	200	ST	PO	3	>100	TR	N/A	NO
SJII	V	Bottlenose dolphin	3	31-May	11:26	12.7637	63.6827	5	ST	SW	3	>1000	TR	N/A	NO
SJII	V	Atlantic spotted dolphin	11	1-Jun	11:56-12:03	15.6615	64.5905	5	ST	SW	3	>1000	TRANSIT	N/A	NO
SJII	V	Leatherback turtle	1	15-May	15:24	11.3072	64.6377	2	NO	RE	3	>100	TR	N/A	NO

Note: N/A = not applicable or not available.

[1] Initial detection denoted by *. A = acoustic and V = visual detection.

[2] When matched acoustic and visual detections were made, the first time given is for the acoustic detection, followed by the time for the visual detection in parentheses.

[3] CPA is the distance at the closest observed point of approach. This is not necessarily the distance at which the individual or group was initially seen, but how close it got to the vessel.

[4] The initial movement of the individual or group relative to the vessel. UN=unknown, NO=no movement, MI=milling, SA=swimming away, SP=swimming parallel, ST=swimming toward.

[5] The first behavior observed. UN=unknown, SW=swimming, BL=blowing, BR=breaching, FE=feeding, PO=porpoising, RE=resting, TR=traveling, DI=diving.

[6] Sea state is recorded based on the Beaufort Wind Force (which is not the same as the "Sea State" or SS scale).

[7] Water depth was recorded for the vessel's location when a sighting was made. Water depth data were usually not available (N/A) for the *Seward Johnson II*, and are thus approximated. Depths shown as >100 m are between 100 and 1000 m; depths >1000 m are between 1000 and 6000 m.

[8] Activity of the vessel at the time of the sighting. SH=shooting airguns, ST=seismic testing, OFF=airguns not firing, TR=when the *SJII* was moving/transiting between OBS stations, OS=when the *SJII* was on station, TRANSIT=when the vessel was in transit to or from San Juan, Puerto Rico, to the study area.

[9] This is the mitigation measure that was undertaken if necessary. PD=power-down, SD=shut-down, NO=no mitigation measure required/undertaken.

[10] Possible bottlenose dolphins seen off watch.

[11] Entered safety zone three times, therefore 3 power-downs.

[12] Possible green turtle sighted by ship's mate.

[13] Probable Atlantic spotted dolphins.